ELEVATORS

A PRACTICAL TREATISE ON THE DEVELOPMENT AND DESIGN OF HAND, BELT, STEAM, HYDRAULIC, AND ELECTRIC ELEVATORS

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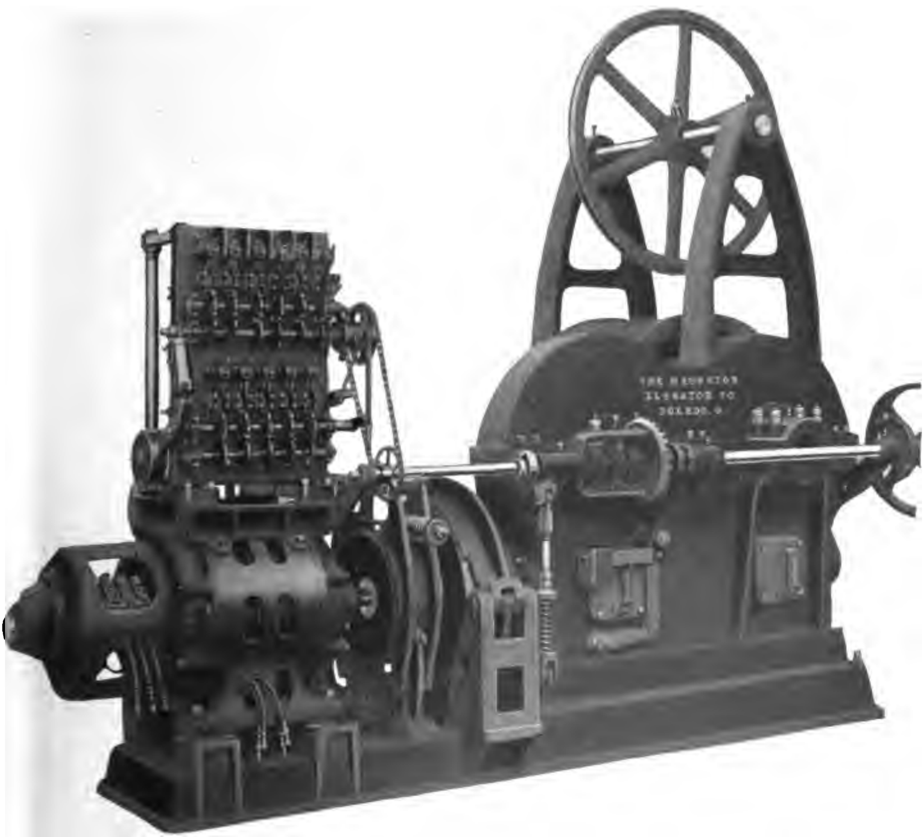
INTRODUCTION

WHEN we see the motormen of our street cars make their crossing stops within a foot or so of the proper place, we call them skilled drivers; when we watch the operators of our swift passenger elevators make stop after stop in rapid succession within an inch of the proper level, we realize not only the skill displayed but also the refinement of the operator's control over the car. Modern elevator service has improved so steadily with the demands made upon it that we hardly realize the perfection which it has reached. From sidewalk lift of one story to the trying service of the Woolworth Building, every requirement either of load or of speed is met with an ease which is truly astonishing.

¶ The history of the development of the elevator is practically the history of the mechanical development of the age. Starting with the crude hand elevator which was confined entirely to the handling of freight, one feature after another was added either as the necessities of the service demanded it or as the mechanical improvement of our machines and mechanicians would allow it. The motive power received its share of attention—hand, steam, hydraulic, and electric motive power being perfected in succession. The two latter alone survived in rendering the difficult passenger service of the modern skyscraper, and in late years the popular favor has been almost wholly transferred to the electric type of elevator. But developments did not stop with the motive power for the complications of service demanded perfect control methods, automatic safety devices, proper car suspensions, and ease and smoothness of running. In the hydraulic type, the pilot valve, accumulator, and the high- and low-pressure systems made this type of service extremely reliable. Wonderful progress has been also made in the electric type by the improvements in motor design, both direct and alternating; the perfection of the full magnet control; and the development of the traction type for high buildings. The push-button system of control, by means of which an operator can be dispensed with and every wish of the passenger can be supplied from any floor of the building, is an interesting example of the flexibility of the electric type.

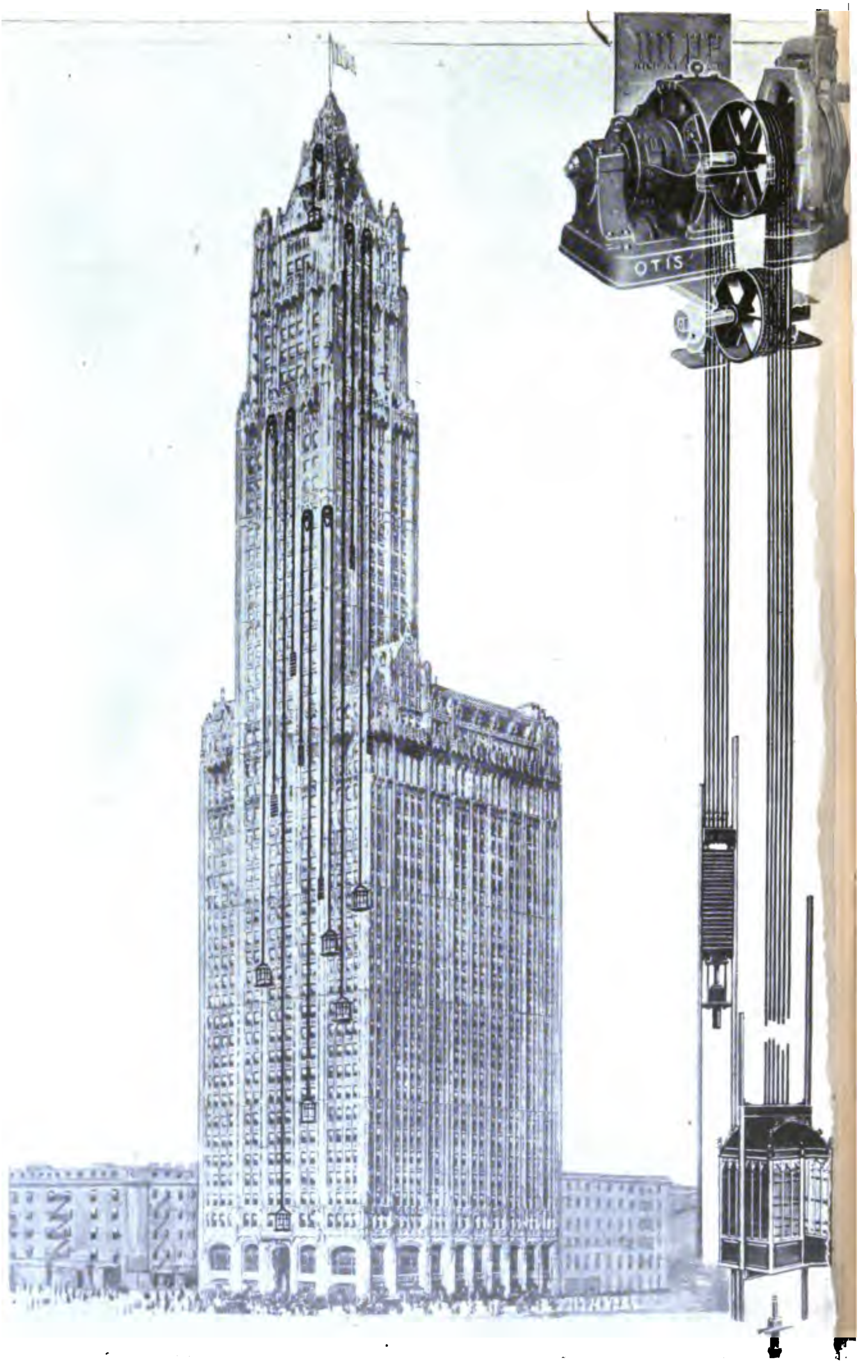
¶ The author has behind him nearly fifty years of actual experience in elevator building and has been a witness of all of these changes mentioned as well as a contributor to the development of a number of them. He is therefore better qualified to speak of the historical development and of the construction of modern types than almost any one now connected with the industry.

¶ The available literature on elevator construction and design is very meager and it is the hope of the publishers that this little volume will find a popular place in its field and satisfy a real demand.



TANDEM GEAR DOUBLE BRAKE ELEVATOR ENGINE WITH VARIABLE SPEED CONTROL

Courtesy of Haughton Elevator and Machine Company



ELEVATOR EQUIPMENT FOR THE WOOLWORTH BUILDING, NEW YORK CITY, AND THE TYPE OF ELEVATOR USED

Courtesy of Otis Elevator Company, New York City

ELEVATORS

PART I

HAND POWER ELEVATORS

HISTORICAL DEVELOPMENT

Fundamental Principles. The development of the elevator to its present state of efficiency has been very gradual, and in this respect it does not differ from the majority of those inventions which have become factors in modern civilization. The stationary steam engine, the locomotive, and the steamboat are instances of inventions which, starting in a very humble way, have by their utility materially assisted in the advancement of business and commerce, and which, in turn, have themselves been developed to meet the increasing demands made upon them.

Undoubtedly the hand elevator, as it is called, or, to be more explicit, the lifting machine operated by manual power, was in existence in one form or another for centuries before the modern appliance with its traveling platform or cage was thought of. The Chinese windlass, the rope tackle, the capstan, and the ship windlass are all primitive forms of the lifting machine which depends on manual energy for its operation, and there is no doubt that the same necessities which led to the invention of these simpler forms of lifts were responsible for later developments.

SLING TYPE

General Construction. Lack of space prevents our going into a lengthy description of the earliest types, and we shall begin with the elevator as it existed some fifty or sixty years ago. At that time the hand elevator was to be found in nearly all warehouses of two or more stories in the form of the "sling machine", so called because of the absence of any platform or cage. The load of goods to be lifted was secured in a strap—or sling—of rope which, in turn, was attached to the hoisting rope of the hand lift, by means of which the load was elevated to the upper story or loft of the building, Fig. 1.

Drum. The apparatus as shown in Fig. 2 included a wood drum or roller about 11 inches in diameter for winding up the hoisting

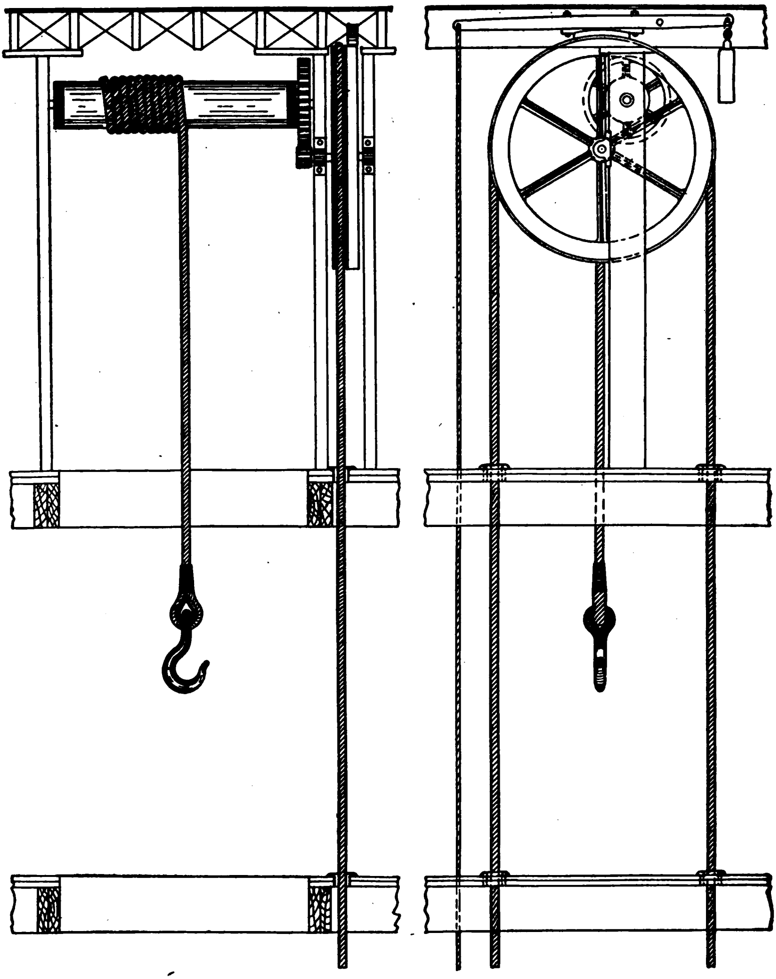


Fig. 1. Front and Side Elevation of Sling Type of Hand Elevator

rope. This drum had a spur gear securely attached to one end of it by staples, and was provided at the ends with gudgeons, or journals, which revolved in babbitted boxes or bearings. The purchase was obtained by means of a spur pinion meshing with the teeth of the gear and a large rope wheel or sheave, both mounted on a short shaft and keyed securely thereto. This shaft was also provided with journals and boxes, the whole being set up in a framework made of wood and securely attached to the building frame in the loft.

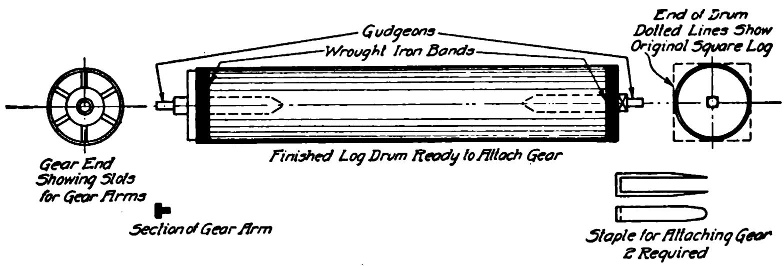


Fig. 2. Details of Finished Log Drum

Below the machine was a "hatchway" or series of floor openings located directly above one another, through which merchandise in bulk was to be handled. The drum was placed directly over the hatchway and the hoist rope dropped down through the opening, the free end

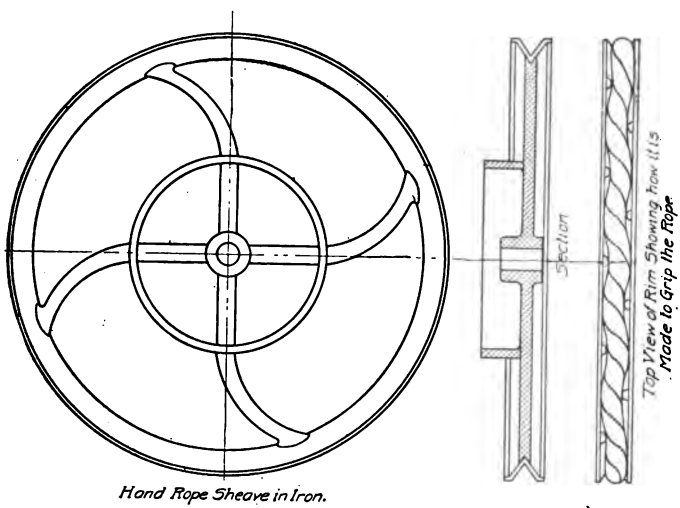


Fig. 3. Elevation, Plan, and Section of Rope Wheel with Ridges Cast in Score

of the rope being provided with a strong wrought-iron hook for attaching to the load to be lifted.

Gearing and Rope Wheel. The ratio of pinion to gear was usually about 5 to 1, the diameter of the large rope sheave was from

4 to 5 feet, and the groove or channel in the rope wheel was V-shaped to prevent the rope from slipping. As a further precaution, small ridges were cast in the score, the ridges being about 12 inches apart and alternating from one side of the channel to the other. This arrangement caused the rope to lie in the channel in a serpentine form, thus effectually preventing slippage, Fig. 3.

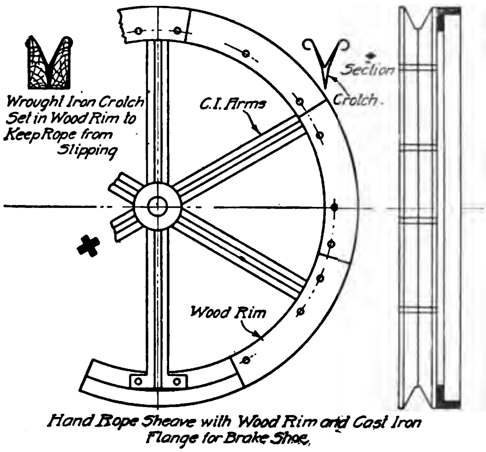


Fig. 4. Details of Rope Wheel with Cast-Iron Arms and Hub

In many instances the large rope wheel, instead of being made entirely of iron, had a cast-iron hub with iron spokes

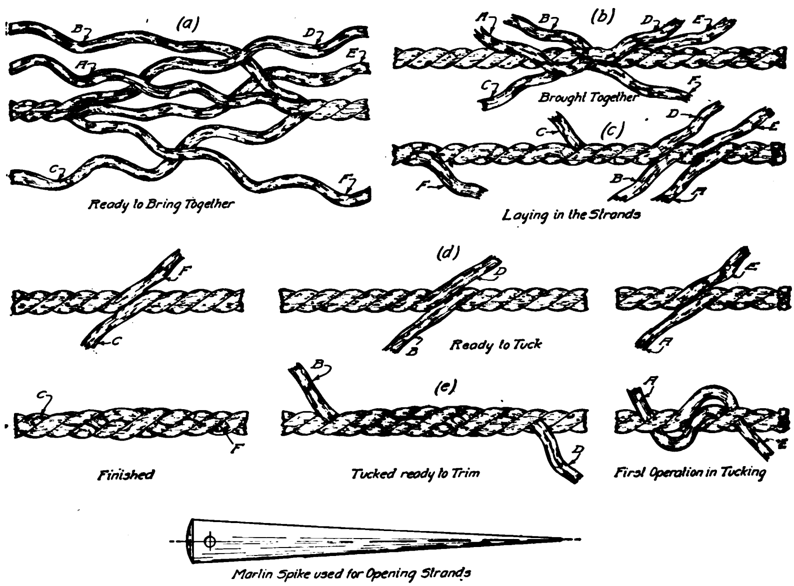


Fig. 5. Diagram Showing Method of Long-Splicing Rope

and a rim of wood made of segments sawed from 2-inch dressed plank nailed and bolted together; a V-shaped groove was turned in the rim or worked out by hand during the process of building up the rim, Fig. 4.

Tackle. The rope used was usually of manila, $1\frac{1}{4}$ inches in diameter, and made endless by means of a "long splice" as shown in Fig. 5, yarns being removed from the rope ends during the process. Before being spliced, the rope was passed or "riven" through holes in the floors of the building, the position of the holes being determined by plumbing down from the large rope wheel after it was in position. Cast-iron thimbles were used to protect the holes from wear, as shown in Fig. 1.

The hoisting rope was usually of $1\frac{1}{2}$-inch diameter, the fixed end being attached to the drum by means of three or four large iron staples made from $\frac{3}{8}$- or $\frac{7}{16}$-inch round iron, spanning the rope and driven into the wood drum at intervals of 5 or 6 inches. The rope was made long enough to reach the lowest floor and still leave several turns around the drum, the spare turns having as much to do with the security of the hoist rope as the staples.

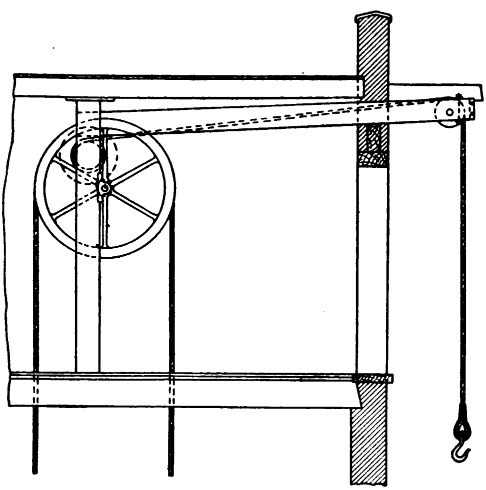


Fig. 6. Details of Outrigger Arrangement for Sling Hand Elevator

The ratio of purchase in a machine such as this was about 25 to 1, the gear and pinion ratio being 5 to 1, and that between drum and rope wheel 5 to 1. Two men, therefore, could easily lift 800 to 1000 pounds two or three stories without undue fatigue, and nearly double that load upon emergency.

Lowering Brake. The lowering of loads was accomplished by means of a brake either in the form of a shoe applied to the rim of the large rope sheave, or of a yoke or a band applied to a pulley cast or bolted on the arms of the wheel. This will be described further on.

Outrigger. In many instances, instead of using a hatchway inside the building, an outrigger was employed, consisting of a heavy beam made of two stout planks bolted together with sufficient blocking between to leave a space of four or five inches in which a large iron sheave was placed near one end for carrying the hoisting rope, Fig. 6. This beam was placed close up under the roof of the building, the sheave-end projecting through the outer wall about three feet. By having a wide doorway at each story directly opposite the lifting rope, goods could be lifted from wagons directly into the building.

The writer has gone somewhat into detail in describing this machine because it is the type from which the hand-power elevator of today has developed, and a clear conception of its features will enable the student to understand the later types.

DEVELOPMENT AND PRINCIPLES OF THE MODERN HAND TYPE

Differences Between Modern and Sling Types. The modern type of hand elevator differs from the one just described in the following particulars:

(1) In the use of a platform or traveling car on which to load the goods to be handled.

(2) In the use of guide rails for the car to travel on.

(3) In the use of antifriction roller bearings to reduce friction in operation.

(4) In the application of a heavy weight to counterbalance the weight of the car.

(5) In the use of wire ropes or cables of smaller diameter and greater flexibility than the old cumbersome manila lifting rope.

(6) In the addition of safety appliance to hold the car from falling in case of the cables breaking.

(7) In the use of an improved form of brake for stopping and holding the car rigidly at any floor while loading and unloading.

These features of the modern type of hand-power elevator will now be discussed in the order given.

These hand-power elevators are made and used today very extensively, finding their greatest field of application in small stores for the purpose of handling goods between the basement and upper floors. Low first cost and simplicity of construction and operation are their chief recommendations, and they fill all the requirements of an elevator where the number of loads to be lifted per day is not excessive; however, care is absolutely necessary in their operation. In the first place, they should not be run unchecked—either down with a load or up without one; and in the second place, they should be securely locked when stopped for loading or unloading. If these precautions are taken, and if proper attention is paid to lubrication, they are both serviceable and durable.

Introduction of Platform. A very important step in the development of the elevator was the introduction of the platform or traveling car, Fig. 7, and a new field for its application was thereby created. Formerly the elevator was employed for handling only goods in bulk, but the introduction of the platform or car made it serviceable in retail stores and other places where it was desirable to hoist or lower smaller packages in quantities.

Necessity for Lightness. Of course it soon became apparent that lightness in weight was a feature which could not be ignored, for, even though the platform may be well counterbalanced, the addition of a counterbalancing weight adds to the

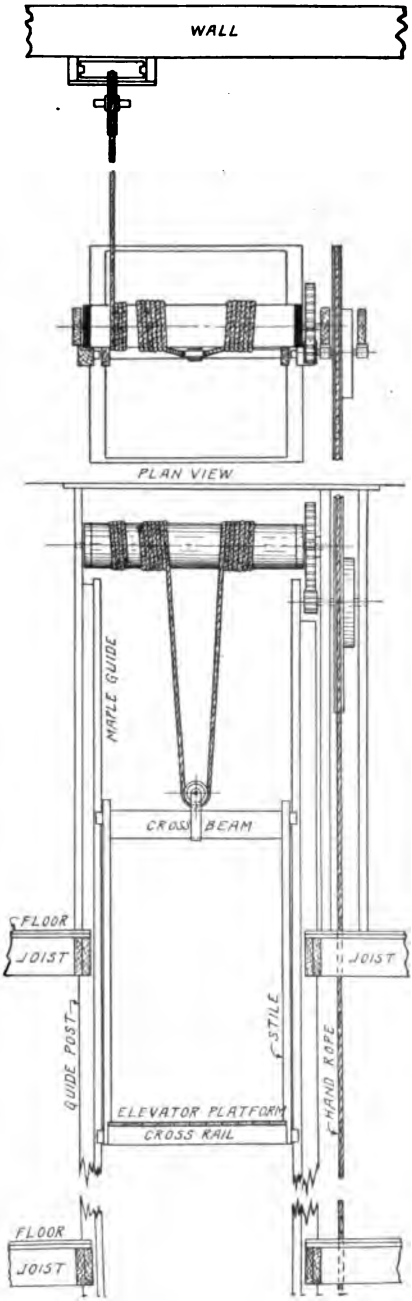


Fig. 7. Evolution of Platform Elevator from Sling Machine

friction in operation, to the inertia in starting, and to the momentum in stopping, thus creating forces which have to be overcome by the operator. Hence platforms for hand elevators are always made as light as may be consistent with the necessary qualities—strength and durability.

Guidepost. Naturally the guidepost and a rail at each side of the hatchway came into use simultaneously with the platform. The first type of rail used was made of cast iron with a flange for attaching it to the guidepost by means of wood screws and with a serrated edge for engaging the safety dogs. This type of rail has passed out of use, and today a wood rail is invariably used. These rails are generally made of maple and are usually $1\frac{3}{4}$ by $1\frac{3}{4}$ inches, being fastened to the guidepost by means of flat-headed wood screws. The guide strip is bored for the screws at intervals of 15 inches, and the holes are countersunk to let the heads of the screws lie well below the surface of the guide strip, this being necessary to prevent the guide shoes on the car from catching on a projecting screwhead.

Kinds of Wood Used. The use of a hard close-grained wood, such as maple, beech, birch, or cherry, for the guide rail is necessary to obtain durability, but the rail must not be too large, for the greater rubbing surface increases the friction, which in turn perceptibly increases the power required to operate the elevator. Moreover, the high cost of these hard woods and their liability to warp are further objections to making the guide and post in one piece. Still it is very essential that the guide be rigid in order to obtain steadiness and stability in operation and safety in case of breaking hoist ropes, thus throwing the safety dogs, in which event the guides cannot be too rigid.

For these reasons it has been found most desirable from every point of view to use a guidepost made of some less expensive wood—one which is not so liable to warp or get out of shape, such as well-seasoned pine or spruce. As a further precaution, the guidepost is usually made up of several thicknesses of 2-inch plank, three pieces 2 by 6 inches or 2 by 8 inches, surfaced on both sides and edges, and spiked together, forming a post of about 5 by $5\frac{1}{2}$ inches or 5 by $7\frac{1}{2}$ inches. Care is taken that one of the sides of each post, i.e., that side to which the guide is to be attached, is straight and true, and that, in setting them in place in the hatchway, they are set to plumb lines so as to be parallel to one another and central between the back and front sides of the hatchway.

Method of Attaching. When these guideposts are in place the hardwood guides or rails on which the car travels are attached, thus giving the additional advantage of permitting the guide rails to be made in short lengths of about 4 feet. This permits the exercise of economy in the manufacture of the rails, as there is a lower percentage of waste when cutting short straight lengths. In order to insure perfect alignment at the joints, the ends of the guide strips are matched, that is, they are alternately tongued and grooved, the tongue on the end of one length fitting into the groove in the end of

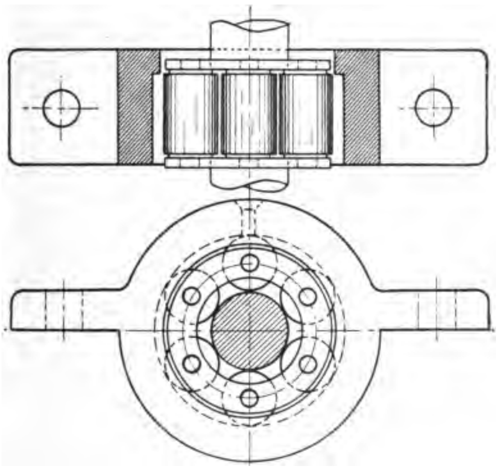


Fig. 8. Details of Roller Bearings for Elevator Drum and Gears

the next. Holes for the wood screws which fasten them to the posts are also provided at about 3 inches from each end and at intervals of about 14 or 15 inches, as stated before.

Introduction of Antifriction Roller Bearings. The use of a traveling car or cage, of course, necessitated the use of a counterbalancing weight to offset the weight of the car, but this additional load on the journals and bearings of the drum and gear caused the machine to run stiffly. This required additional exertion on the part of the operator and thus detracted from the advantage gained by the convenience in handling goods. Attention, therefore, had to be given to this feature with the result that the "antifriction roller bearing" was developed, comprising a set of rolls on pins running in circular frame a or cage made of two rings, as shown in Fig. 8. The rollers are usually made of cold-rolled Bessemer-steel shafting, $\frac{15}{16}$ inches in diameter, cut off in lengths of about $1\frac{1}{2}$ inches, chucked true in the lathe and bored for $\frac{5}{16}$-inch pins designed to run loosely, and faced on the ends. Six of them are then assembled between the two rings shown in Fig. 8, and a special box or case is provided for them to run in, as shown in Fig. 9. It will be noted that different forms of boxes are shown, the difference being only in the height of the center of the box above the bases provided for attaching them to the wood frame. This difference in height is due to the difference in the diameters of gears and pinions used, and to the need for keeping

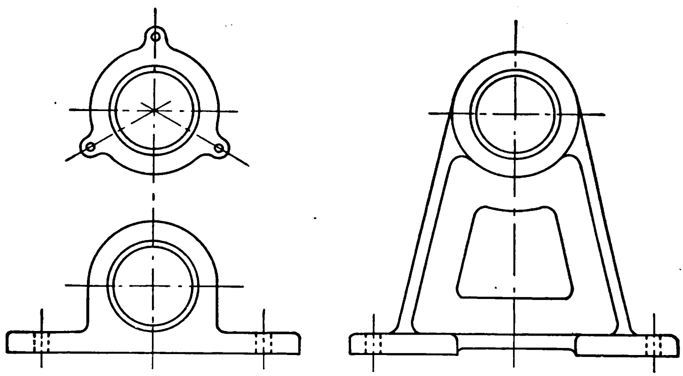


Fig. 9. Different Types of Boxes for Roller Bearings

the centers of the drum- and pinion-shafts within certain fixed limits determined by hatch size and rope-wheel, drum, and gear diameters. The difference is merely a matter of convenience, the box being always the same. The use of antifriction roller bearings in connection with hand-elevator gearing produces such a marked improvement in the ease with which the elevator can be operated that no experienced builder thinks of making a hand elevator without using them.

Necessity for Oiling. Although many makers claim that such bearings will run without oil, this is a fallacy; for, although they will run without lubrication, they wear out very quickly under such conditions, while, when properly lubricated, they will last for years. It is therefore both prudent and economical to lubricate them at intervals of once or twice a month with a small quantity of oil. Oil is principally needed on the pins upon which the rollers run, and at the ends of the rollers where they bear against the shoulders of the journals and bearings. If oil is put into the box through the oil hole at the top, it will distribute itself properly, provided a sufficient quantity is used.

Early Type of Counterbalancing Weights. The first counterbalancing weights used were very crude affairs, being simply long rectangular pieces of cast iron with an eye cast in one end for attaching the rope from which they were hung. They were allowed to run in a pocket located against a wall at some distance from the hatchway, the weight rope being led from the drum and over a sheave set above the weight pocket, in a manner somewhat similar to the way in which the hoisting rope in the outrigger type of the old sling machine was led to the sheave outside the building.

Means Employed to Keep Rope Plumb. This arrangement was largely due to the room that several turns of the manila rope required on the drum, a circumstance which prevented leading the rope down inside the hatchway and locating the counterpoise weight alongside the guidepost. The same difficulty was met in the case of the hoisting rope because the room it required on the drum, when several turns of rope were wound upon it, made it impossible to keep the hoisting rope hanging plumb in the center of the shaft, thereby causing the cage to be pulled sideways against the guides and giving rise to considerable friction. To overcome this defect, it was customary to use a longer hoist rope, fastening both ends of the rope to the hoisting drum and passing the loop through a sheave about five inches in diameter in the lifting strap of the car, Fig. 7, the sheave being used primarily to avoid abrading the hoist rope. The car then hung in the bight of the rope, that is, the loop formed by attaching both ends to the drum as described, with the result that the drum wound up both portions of the rope, causing the car to be lifted centrally. In attaching the ends of the rope to the drum, space was left to permit the rope to be wound up, as shown in the illustration.

Served-Rope Hoist. The ropes were also kept plumb by using sheaves with V-grooves similar to that in the large rope wheel, the sheaves being firmly keyed on a shaft which displaced the log drum, and which also had the spur gear keyed on it. The sheaves were about 14 inches in diameter and the shaft about $2\frac{1}{4}$

inches, the gear remaining about the same as it had been on the drum machine, that is, about 24 or 26 inches in diameter with a

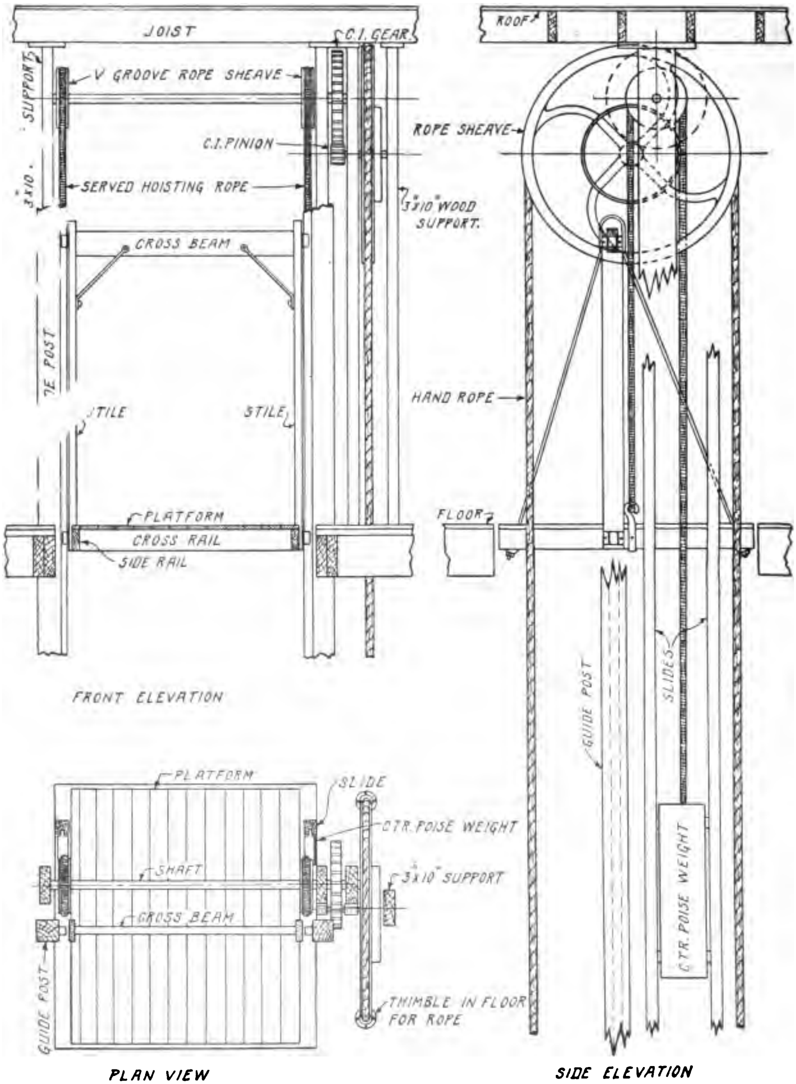


Fig. 10. Details of Hand Elevator Showing Use of Served-Rope Hoist

tooth pitch of 1 inch. Two hoist ropes about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter were used, one end of each rope being attached to the bottom of the car close behind the guides, which, to allow of a central lift, were set 4 inches to the front, as shown in Fig. 10. The other ends of the hoist ropes, after being led up to the top of the hatchway and over the 14-inch sheaves, were attached each to one of the counterpoise weights located on each side of the hatchway. With this arrangement there were two counterpoise weights and two hoist ropes, and the weights ran in open slides inside the hatchway. The load was lifted entirely by friction, that is, by the gripping of the hoist ropes in the V-scores of the 14-inch sheaves. To prevent wearing of the hoist ropes it was necessary to give the hoist ropes a protecting covering before putting them in place. This was done by "serving" or covering them with a thickness of marline wound on tightly while the ropes were stretched. When this protection wore through, it had to be renewed. The counterpoise weight on one end and the car at the other, as shown in Fig. 10, caused the ropes to sink into the V-grooves sufficiently to give the necessary traction to lift the load.

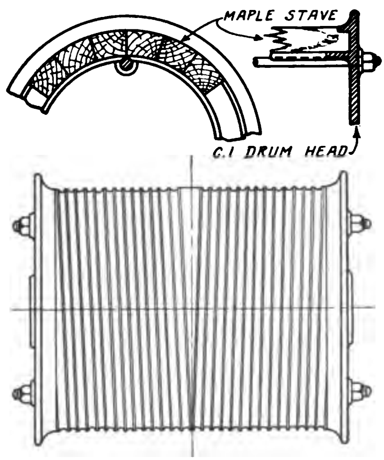


Fig. 11. Details of Hand Elevator Drum

Introduction of Wire Ropes. When flexible wire ropes of circular cross section came into use they replaced the manila hoisting ropes on elevators, but the introduction of wire lifting ropes necessitated changing the drums so as to render them suitable for the purpose. As side-lifting manila ropes were already in use, the first wire ropes used were attached to the car and to the counterpoise weights in the same way. In order to give sufficient tractive force, the body of the drum used was made of wood, hard-maple staves, thoroughly dried, of keystone or wedge section being employed. These were fitted together as shown in Fig. 11, and held in position by two cast-iron flanges or drumheads, Figs. 11 and 12, bored and keywayed to fit the drum shaft. The resultant drum was put in the lathe, and the outside of the wood center, or barrel of the drum, was first trued or turned cylindrical; then a spiral groove to fit the cable was turned in the surface, the pitch of the spiral being a little greater than the diameter of the cable or rope, in order to prevent the turns of rope on the drum from touching one another. When up in place, the wire ropes were wrapped around the drum about three times, one end of each cable being attached to one of the side rails of the car bottom and the other end to one of the weights. This arrangement gave sufficient traction to lift the required load, and the

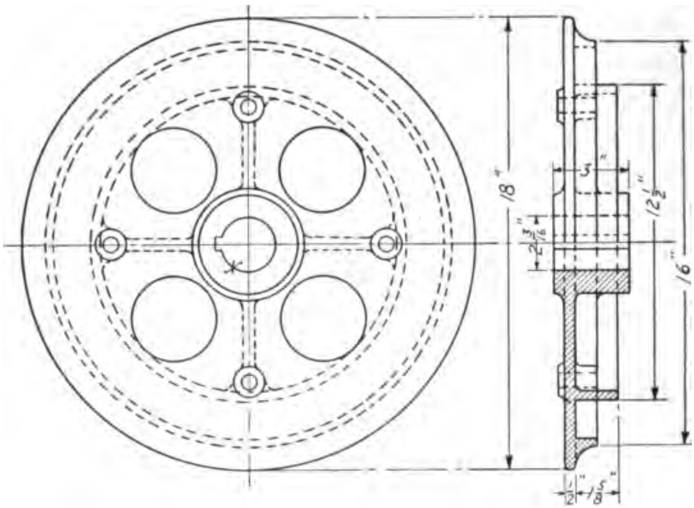


Fig. 12. End View and Part Section of Drum Heads for Wire-Rope Elevator

resultant machine was a more efficient, easier-running, and altogether more satisfactory elevator than any yet produced.

Adoption of Center Lift. The increasing height of buildings soon brought out defects which hitherto had not been suspected, for, with the increased travel of the car, it was found that the longer drums did not always wind the cables evenly. It was discovered also that the drums must be turned not only parallel but that both had to be of exactly the same diameter, a slight difference in their respective diameters causing a very perceptible difference in the level of the floor of the car during its travel in the higher buildings. As a result of the efforts to remedy this trouble, the first idea of lifting from the center of the crossbeam of the car, as shown in Fig. 13, was again brought into use. This proved entirely successful, and today the center lift is the popular form of hand-power elevator, although many makers for machines of short travel of one or at most two stories use the side lift; in these cases, however, economy in first cost,

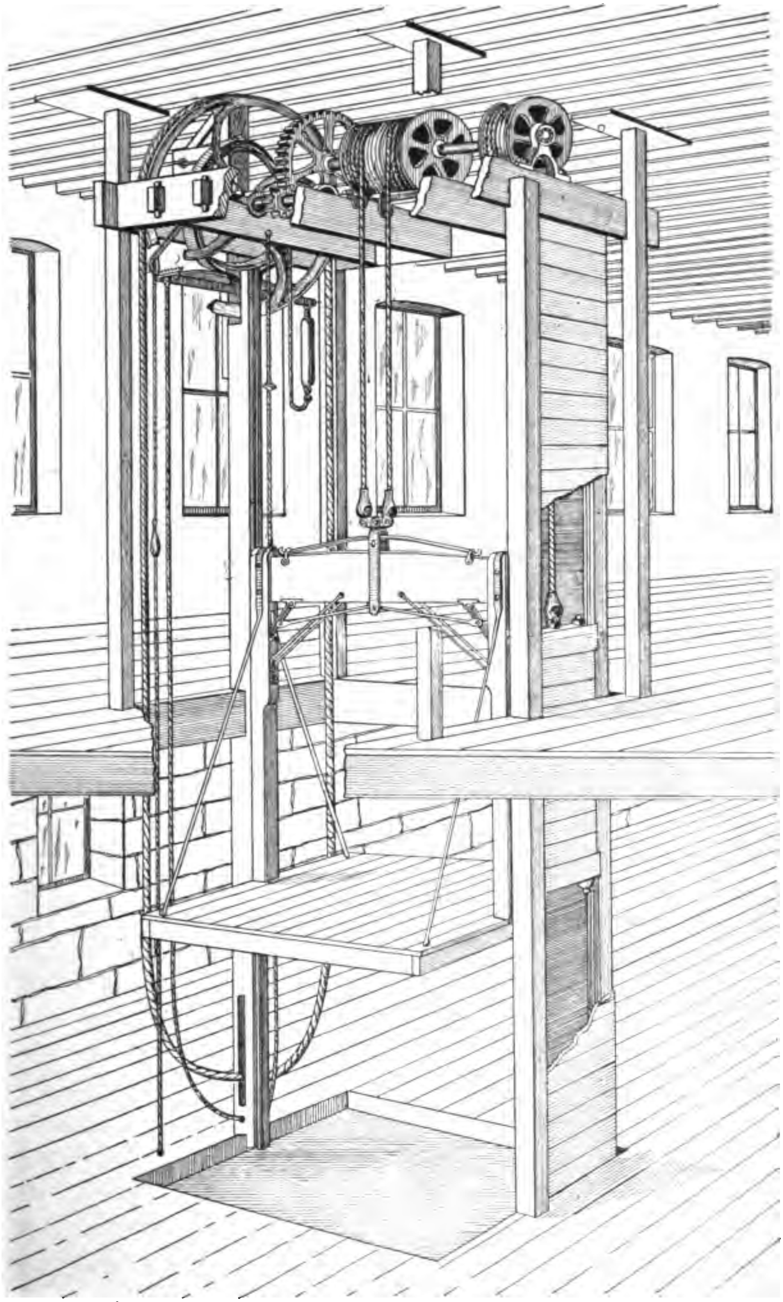


Fig. 13. Detail Views of Center-Lift Elevator with Grooved Drums and Wire Ropes

or the production of a cheap elevator, is the incentive. To further this object of low first cost, the drums are dispensed with and a V-grooved sheave is used, having the V form an angle of about 35 degrees. Wire rope instead of the served manila rope is used, but such machines are neither desirable nor lasting, and they quickly destroy the lifting cables.

Counterpoise Weights. It was found to be desirable in most cases to make the counterpoise heavier than the car, so that when the car was empty and stationed at one of the lower floors, it would be possible to cause it to rise of itself to the upper floor at which it was wanted by simply releasing the brake, stopping it upon its arrival, and locking the brake. The improved counterpoise weight was formerly made in the form of a cast-iron frame having guides or guide shoes cast integral with the frame, the center of the weight being filled, or partly filled, with smaller weights, called sub-weights, until it was heavy enough.

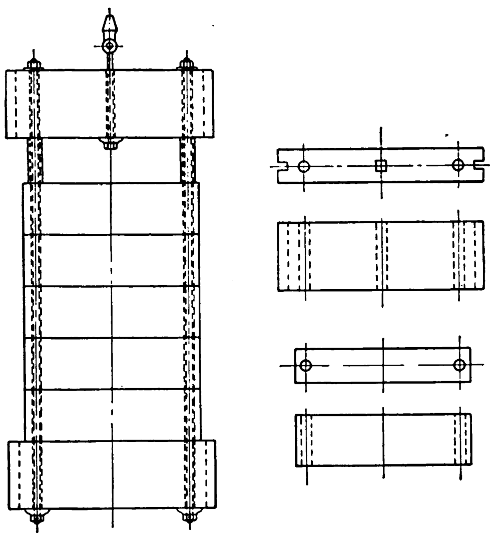


Fig. 14. Elevator Counterpoise Weights, Showing Method of Fastening

Modern Type. The counterpoise weight of today is made up of a number of small weights, the top and bottom weights having the guide shoes cast on them, Fig. 14. The shoes travel on weight guides, which are similar to those on which the car travels but usually smaller in section, being either $1\frac{1}{4}$ by $1\frac{1}{4}$ inches or $1\frac{1}{2}$ by $1\frac{1}{2}$ inches. These weight guides are attached to guideposts similar to the car guides but smaller in section. They are usually made out of a single piece of timber 3 by 4 inches, 4 by 4 inches, or 4 by 6 inches, according to the size of the weight which is to run in them.

The sub-weights of the modern counterpoise weight are similar to the top and bottom weights, but have no guide shoes. Both the main and sub-weights have holes cored through them near each end for the admission of long rods of $\frac{5}{8}$- or $\frac{3}{4}$-inch round iron. When the correct number of weights have been assembled, including the top and bottom weights, rods are passed through the holes, as shown in Fig. 14, the rods having been previously cut to the proper length and threaded for a distance of 5 or 6 inches at each end. Washers and double nuts are put on, and the whole is bolted together into one

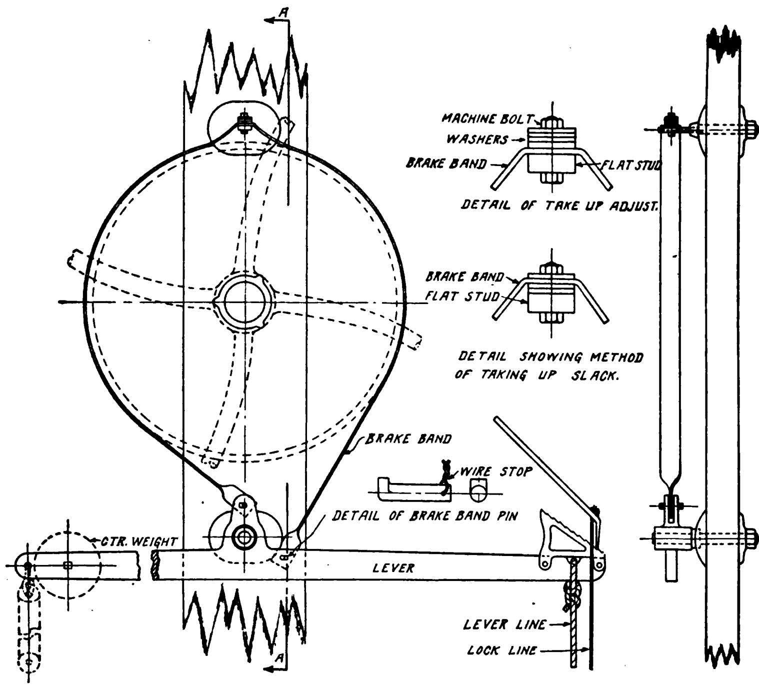


Fig. 15. Construction of Steel-Band Type of Elevator Brake

solid compact weight. The advantages of this method are obvious, as changes in the adjustments can easily be made at any time.

It was also found desirable in many cases to place the hand or pulley and brake ropes inside the hatchway, thus enabling the operator to ride up or down with the load on the car and be on hand to unload the goods. Here the extra amount of counterbalance weight proved to be of advantage, as the excess weight, being usually about 200 pounds, was also capable of lifting the man. The amount of overweight varies with the conditions of operation. If a truck is constantly used with a load, the counterweight can be made to include also the weight of the truck, thus reducing to a minimum the manual labor required to operate the elevator.

Brakes. *Steel-Band Type.* In modern hand-power elevators the brake nearly always takes the same form, i.e., that of a steel band $\frac{1}{8}$ inch thick by $1\frac{3}{4}$ inches wide, Fig. 15, wrapped once around a pulley cast on the large rope wheel, the ends being attached to the

Fig. 16. Rope Hoist with Band Brake but without Ratchet and Locker
Courtesy of Warsaw Elevator Company, Warsaw, New York

brake lever and the center of the band supported by a stud attached to a suitable portion of the wood frame which carries the gearing. When the end of the lever is pulled down, it causes the band to clasp the pulley in a vise-like manner, and thereby stops the motion of the wheel and, through the medium of the intervening mechanism, the elevator also. A weight attached to the other end of the lever causes it to release the band when the brake rope is let free.

When it is desired to hold the platform at any one point after it has been stopped, the teeth of a dog or pawl called the locker are caused to engage in a ratchet bolted to the end of the brake lever, thus holding the brake on tight, so that the platform may be loaded or unloaded with safety. When it is desired to release the brake, a strong pull on the brake line causes the ratchet to become disengaged from the locker, and the brake is free again.

The brake shown in Fig. 16 includes the brake band and lever previously described, but minus the ratchet and locker. The end

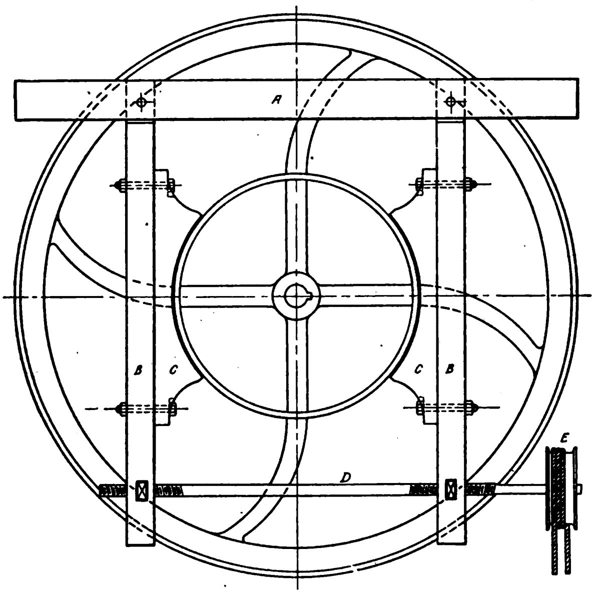


Fig. 17. Construction of Wood Shoe Brake

of the lever is slotted, as shown at *B*, and in this slot a crankpin on the sheave *C* operates to move the lever. In the position in which the lever is shown the brake is on, but when the sheave is turned one-half revolution backward the brake is released. The machine here shown is a modified form of the old-fashioned sling machine previously described, but has a cast-iron drum instead of the wood drum, and a wire cable instead of the manila rope to lift the load. It is not a type to be recommended, as it is bad practice to use a cast-iron frame for a tensile strain, and it is only introduced to show this form of brake application.

Wood-Block Type. Another and very effective form of brake is shown in Fig. 17. It is somewhat crude in appearance, but it is found in practice to be very easy of operation and very powerful; it also has the advantage of not having to be locked, as it stays in whatever position it is placed. Its chief disadvantage is the necessity for using both hands when lowering a load, one hand being used for applying and the other for releasing the brake as occasion may require.

Referring to the illustration of this brake, *A* is an upper or crossbeam made of 3- by 4-inch hard wood, into which are tenoned two vertical pieces *B* of the same dimensions. These tenons *B*, are made to fit somewhat loosely into their respective mortises and are held in place by bolts or pins. To them are bolted two brake shoes *C*, usually of maple, sawed out in the band saw to fit the brake pulley. The vertical parts of this yoke are connected at their bottom ends by means of a long rod *D* of $1\frac{1}{4}$-inch round iron having at the proper distance apart a right- and a left-hand screw. This rod passes through the lower ends of the vertical pieces *B*, nuts fitting these screws being let into mortises in the pieces of wood. A sheave *E* is keyed on one end of the rod, and a rope attached to the periphery of the sheave is wrapped several times around it, the ends being led down the hatchway. Pulling on one side of the line turns the rod in a direction that causes the right- and left-hand screws and nuts to clamp the pulley in a tight grip; while pulling on the other side of the line, of course, reverses the motion and releases the brake.

Safety Dogs. *Unreliability with Side-Lift Machine.* With the side-lift machine suitable safety devices had been difficult. If only one cable broke, the immediate result was to rack the car, for it is assumed that the hoisting cables would break only when under strain or, in other words, when the car was loaded and the sudden letting down of one side of the loaded platform would distort the frame, throw it out of square, and tend to force the guideposts apart, thus ruining a most important member of the apparatus. Consequently the efforts of the makers were directed to devise a scheme to throw the safety dogs on both sides simultaneously with the breaking of either of the cables. To accomplish this end, both counterpoise weights were connected with the dog-throwing device by means of idle lines. These lines were not expected to do anything unless a cable broke, when the weight in dropping would pull the idle line, or safety line, as it was called, and it in turn would throw in the dogs.

Although this looks like a very simple and ingenious arrangement, it proved in practice to be quite the contrary. The safety lines being of manila, frequently became tangled with other moving parts of the machine; and sometimes persons operating the elevator, being ignorant of their purpose and regarding them as superfluous, would cut them loose and remove them entirely.

Relative Simplicity with Center-Lift Type. With the adoption of the center-lift form of hand elevator the problem of the safety device became simplified, because where the lift is from one point, and that point the center of the car, it was only necessary to make the lifting strap movable through a few inches in a vertical line and arrange it so that tension on the lifting cables would hold it up to its highest point of travel. Operation could then be obtained by the application of a strong spring to throw the strap down when the tension on the cables was released. This strap was connected with the safety dogs or nippers by means of suitable levers, and the object sought was accomplished.

Floor Thimbles and Rope Guides. When the hand rope runs through the floors of the building, a cast-iron thimble is inserted in every hole in each floor through which these ropes run. Thimbles for large ropes have a hole about 3 inches in diameter and a flange about 1½ inches in width through which are drilled holes for wood screws to hold them firmly in the floor. The thimbles for the smaller ropes have a hole 1 inch in diameter and a similarly proportioned flange. When the hand ropes run inside the hatchway, guides are attached to the trimmers of the hatch, but only at the top and next to the lower floors. The rope guides are also of cast iron, shaped as shown in Fig. 18, and are attached by lag screws to the hatch trimmers, as shown on Fig. 19. These guides are necessary to keep the hand rope from swinging to and fro, when the elevator is in operation. The

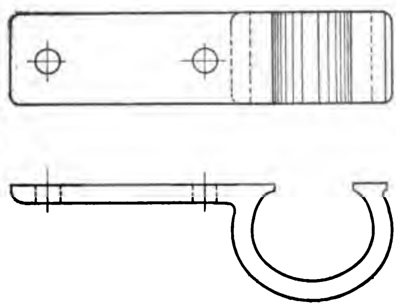


Fig. 18. Cast-Iron Rope Guide

pulling on the rope during the process of hoisting and the sudden application of the brake in lowering produce a violent swaying, pendulum-like motion in the rope when these rope guides are not used, thereby causing the rope to become wedged in between the platform and hatch trimmer, and frequently making the rope jump from its place in the rim of the large rope wheel. However, where these rope guides are used this trouble is eliminated.

Importance of Fundamental Principles. It may seem to the student who reads this article on hand elevators for the first time that the description of the historical development of these improvements is unnecessarily diffuse, but it is suggested that the reader withhold his judgment until he is better acquainted with the subject of elevators. He should take pains at this time to impress on his mind all the salient features of this particular type of machine, as well as the causes which led to its development. It is highly essential that he should do this for the reason that he will find these features constantly recurring in the other types of elevators described later. He will find that the principles evolved in the development of this type of elevator have been introduced in a multitude of cases in the more advanced types of elevators, for the simple reason that nothing better has so far been devised. The experience gained in the use of the scored drum; in the method of scoring it; in the use, construction, and application of the counterpoise weight; in the use of guides, safeties, and sheaves; in the methods of directing the cables, of braking, of stopping, and of locking; in the use of traction by using several turns of cable around drums, and in many other ways, has been of great service to the elevator builder in the successful development of the modern more powerful and rapid elevators which depend on other

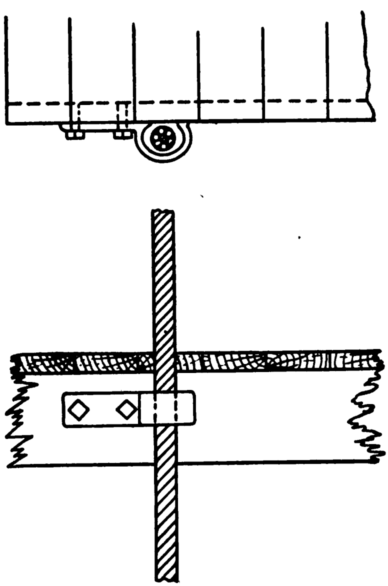


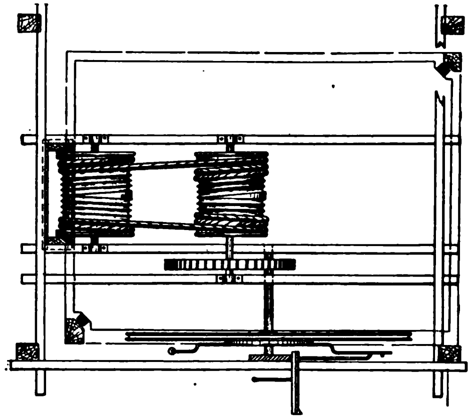
Fig. 19. Method of Fastening Rope Guide to Hatch Trimmer

sources of power for their operation.

SPECIAL TYPES

In the preceding pages the general construction and development of the hand-power elevator have been briefly described. Many modifications of this machine are found at times to be desirable in order to suit varying conditions, and two or three of the most important variations will now be discussed.

Lift with Pulling Rope Near Weight Slide. Sometimes it is found desirable to locate the hand or pulling rope at a side of the hatchway adjacent to that on which the counterpoise weight is to be placed. In such case the hoisting drum is not arranged on the same shaft with the weight drum, but each drum has a separate shaft with appropriate journals and boxes. In making up the frame which carries the gearing, the weight drum is located directly behind the hoisting drum, as shown in the plan view,



— *Plan View of Frame and Machinery*

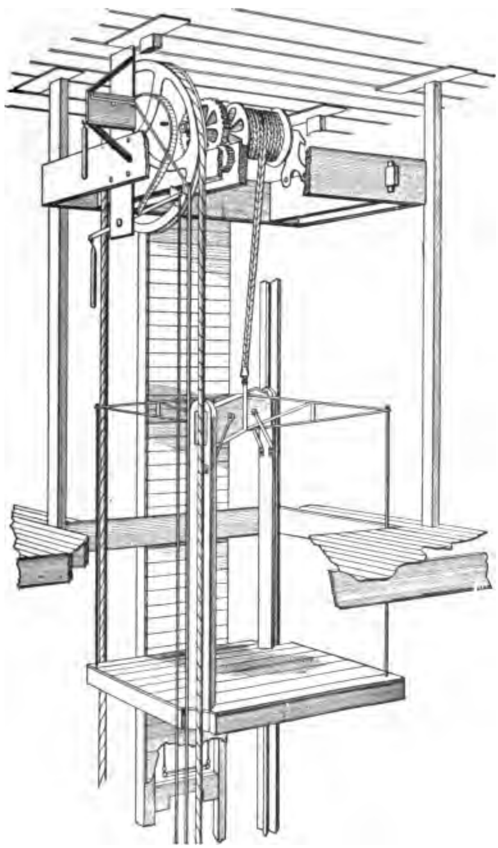


Fig. 20. Details of Corner-Post Elevator

Fig. 20. In that case there are only two cables, and each cable runs directly from the car up to and twice around the hoisting drum, thence across to and once around the weight drum, and from there down to the weight, the general arrangement in other respects being the same.

Corner-Post Elevator. In cases where the entrance to the platform from all sides is desired, it is found essential to

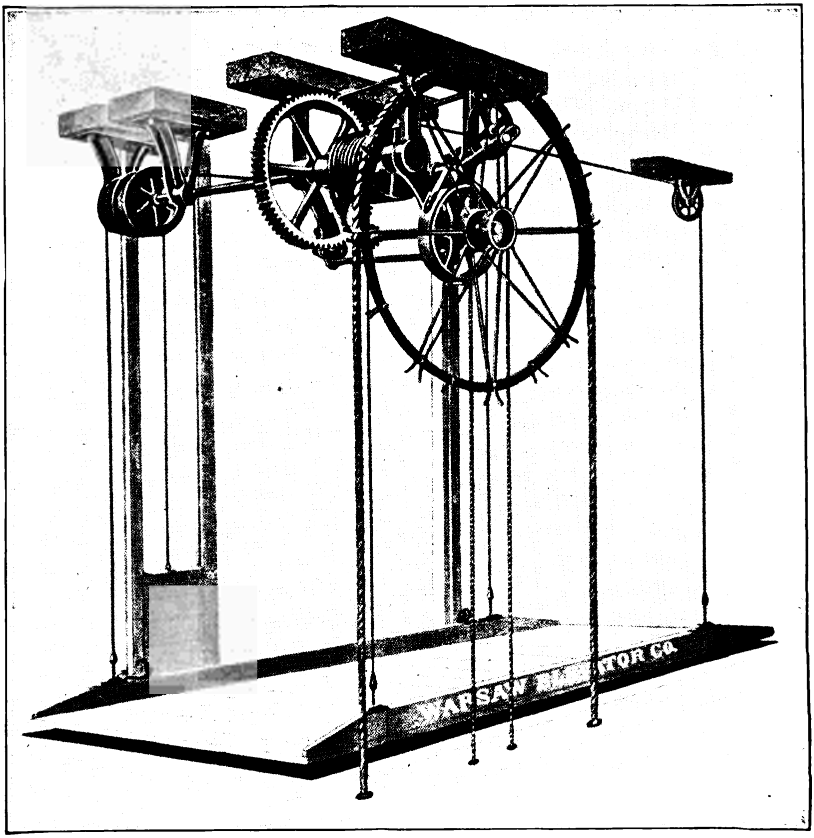


Fig. 21. Carriage Elevator with Two Hoisting Drums and Guides Only on One Side
Courtesy of Warsaw Elevator Company, Warsaw, New York

place the guides at opposite corners of the hatchway, forming what is called a corner-post platform. This feature is combined in the elevator shown in Fig. 20.

Wagon and Carriage Lift. Where it is desired to lift long and bulky articles, such, for instance, as wagons and carriages, another and different arrangement is resorted to, as shown in Fig. 21. In this case two drums on one shaft are used, both being hoisting drums, but one being made longer than the other for the purpose of winding and unwinding the weight cable. Two hoisting cables are used on the hoisting portion of each drum.

The frame which carries the overhead work or gearing is set above one end of the long platform, and two hoisting cables are led directly down from these drums to one end of the two sides of the platform. To lift and lower the other end in unison, two additional cables are attached to the same drums and led from there to sheaves located at the opposite end of the hatchway, and thence down to the other end of the platform. By this arrangement the platform is lifted

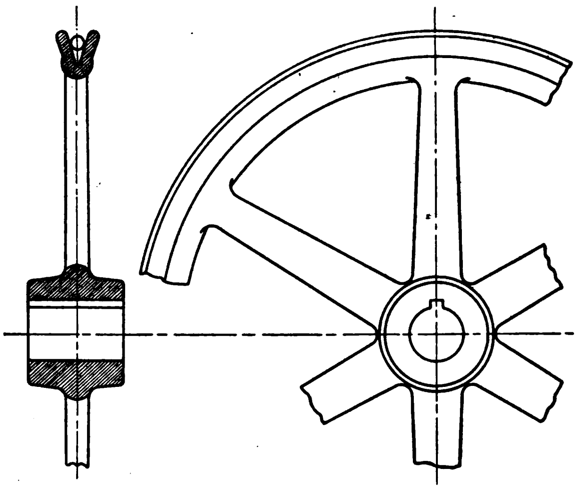


Fig. 22. V-Grooved Hoisting Sheave for Light Hand-Power Elevators

at its four corners, so that no stiles or uprights are needed, nor is a crossbeam used, and guides are required on only one side of the platform. It is customary to utilize the weight slide as one of these guides, a separate guide being placed near the other end of the platform on the same side as the weight slide. The arrangement and construction have been shown in detail in previous illustrations.

Light-Load Sheave-Type Elevators. When the load to be lifted does not exceed 800 pounds another modification is used. Every part of the framing and gearing is made the same but somewhat lighter in proportion, the principal difference being in the use of a sheave instead of a hoisting drum. This sheave has a V-shaped groove for the cable to run in, one end of the cable being attached to the top of the car or platform. After being carried up and over the sheave, the other end of the cable is attached to the weight, the sheave being made large enough in diameter to span the distance between the center of the car to the center of the weight slide, so that both

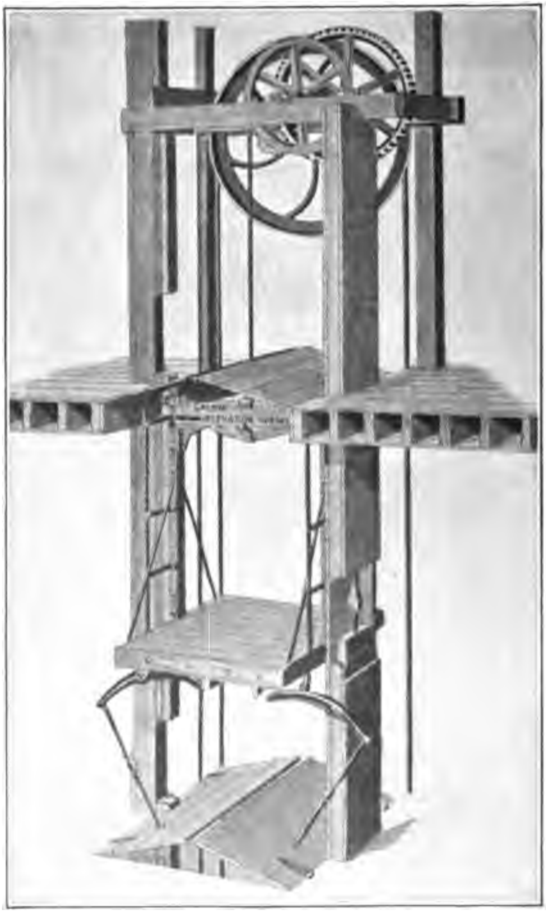


Fig. 23. Hand-Power Elevator with Automatic Safety Doors
Courtesy of Salem Elevator Works, Salem, Massachusetts

ends of the cable hang plumb. Fig. 22 shows the type of sheave used, and Fig. 23 its application to an elevator with the added feature of automatically operated trapdoors.

Before closing this article on lifting machines operated by hand power, it might be well to give a brief description of two other forms of the machine which, although not so frequently met with as those just described, are nevertheless very useful in their way and of interest on that account. We refer to the basement or sidewalk lift and the dumb-waiter.

BASEMENT ELEVATOR

This machine, as its name implies, is used for lifting loads through the height of only one story, usually from the level of the basement floor to that of the ground floor, or of the sidewalk.

Four-Chain Type. *General Construction.* Figs. 24 and 25 give a good idea of the general form of the 4-chain type. The platform on which the load is placed is lifted at the four corners by means of chains which run over sheaves or pulleys, their bearings being set in frames which bring them level with the ground floor or sidewalk. The lifting chains, after passing over the sheaves, are led down to the hoisting drums *A* below, Fig 24. The drums are keyed securely on a shaft, to one end of which is attached a spur gear revolving in bearings located below the level of the basement floor. The drums are placed a sufficient distance apart on the shaft to allow the platform to pass between them, and far enough below the floor level to permit the platform to descend to the level of the floor without striking the shaft.

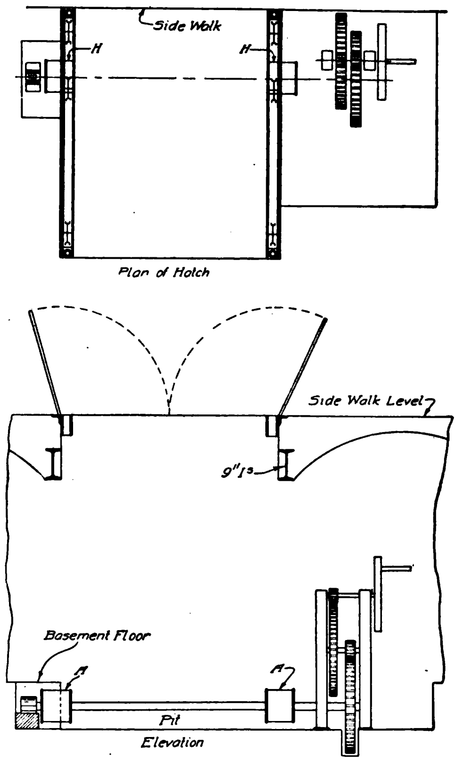


Fig. 24. Gear Drum and Sheave Arrangement for Basement Elevator

The spur gear, previously mentioned as being at one end of the shaft, meshes with a pinion which is a portion of a train of gears and pinions keyed to shafts running in bearings in a cast-iron frame.

The first or upper shaft is provided with a hand crank, Fig. 24. The second shaft in the winch has a brake pulley keyed to it, a brake band and lever being provided to effect the application of the brake

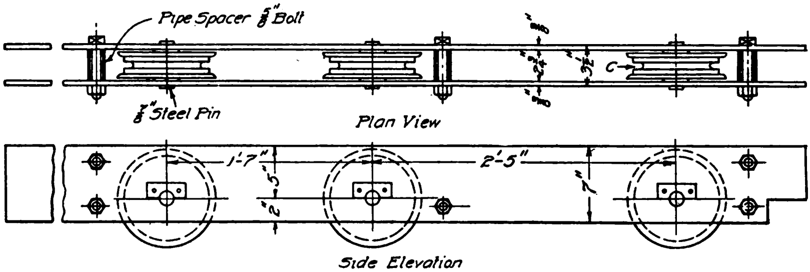


Fig. 25. Plan and Side Elevation of Sheave Bars for Basement Elevators

when needed. There is also a pawl or dog attached to the frame which, when called into play, drops or meshes into the teeth of the first gear. A purchase of about 26 or 30 to 1 is usually employed.

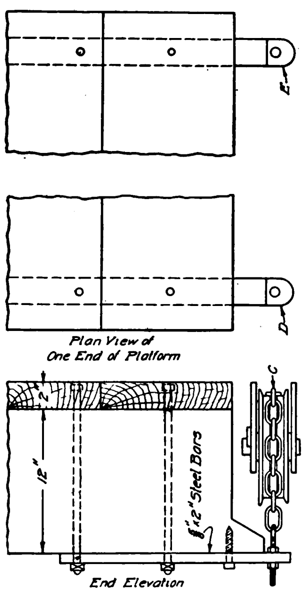


Fig. 26. Details of Platform for Basement Elevators

Sheaves and Sheave Bars. Fig. 25 shows the construction, details, and typical dimensions of a set of sheave bars. They are usually made of bar iron $\frac{3}{8}$ to $\frac{1}{2}$ inch in thickness and either 6 or 7 inches wide, depending on the length of bar and load to be lifted. The sheaves are about 9 inches in diameter, and are of cast iron bored to receive a $\frac{7}{8}$-inch steel pin which is kept in position by means of a flat plate at one end. This plate, as shown in Fig. 25, is bolted to one of the bars by means of tap bolts and fits into a slot cut halfway through the pin near one end. This arrangement not only keeps the pin in place but effectually prevents it from turning, thereby making it necessary for the sheave to revolve on the pin. Oiling facilities are provided in the sheave in the form of a small oil cup screwed into the hub of same.

Chain Arrangement. The sheaves are provided with a double groove, which permits the chain to lie evenly in the sheave, as shown at *C* in Figs. 25 and 26. The sheaves, as can be seen from the side elevation in Fig. 25, are set in position in the bars so that the flanges of the sheaves are slightly below the upper edge of the bars, and so that the two outer sheaves on each bar permit the chains to drop plumb to the irons *D* and *E*, Fig. 26, on the lower edge of the cross rail of the platform to which they are attached. The intermediate

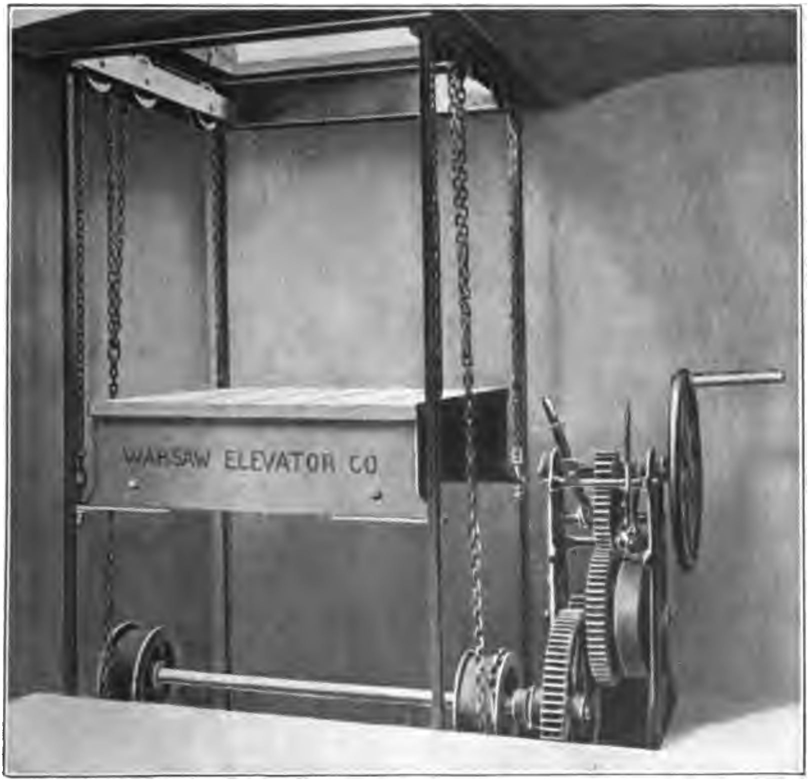


Fig. 27. Complete Hand-Power Basement Elevator
Courtesy of Warsaw Elevator Company, Warsaw, New York

sheave, which is only a leader for one of the chains, is usually set about 18 or 19 inches from one of the end sheaves. The drum shaft is set in the pit, so that the hoisting sides (see *H*, Fig. 24) of its drums are vertically below the center point between each of the two pairs of these nearby sheaves. The end of each chain is attached to each drum by a bolt passing through the last link, and through a hole drilled in the rim of the drum and secured there by means of a nut.

Platform. The platform is made of 2-inch oak, maple, or hard pine. Fig. 26 shows a top and end view of one side of the platform. The cross rails are about 12 inches deep, and the pit or depression in the floor is about 14 inches deep, thus permitting the top of the floor of the car to come even with the floor of the basement. The arrangement and mounting of the platform, chains, and sheaves can be seen in Fig. 27.

Guides. The platform travels on guides, usually located one at each corner. These guides are made in several forms, being usually either of 2-inch iron pipe or of 3- by 3- by $\frac{3}{8}$-inch steel angles, or in some cases of square bars of iron $1\frac{1}{4}$ by $1\frac{1}{4}$ inches. All are satisfactory if sufficiently rigid. The upper ends of these guides are fastened to the frames which carry the chain sheaves, and the lower ends are fastened below the floor of the pit in which the shaft and gearing of the machine for this type of elevator are located.

When pipes are used as guides and supports as well, flanges are screwed on the lower ends of the pipes of sufficient outside diameter to give them a firm bearing when bolted to the pit floor. As the upper ends of the guides terminate just below the sheave bars, the cross rails of the platform must be deep enough to keep the guide shoes on the rails when the platform is level with the first floor or sidewalk.

When either pipe or angle irons are used for guides they frequently form supports for the sheave frames, but where possible the ends of the sheave bars are made to project beyond the guides a sufficient distance to permit them to rest on ledges left at the ground level to carry them.

Operation. Raising the platform is accomplished by simply turning the crank generally in a clockwise direction, Fig. 27. A pawl or dog attached to the frame of the winch directly above the first spur gear drops into and engages the teeth of the gear, thereby preventing its turning in the opposite direction. The car is hence locked against downward movement during the period of raising and of loading at the upper level.

To lower the car it is necessary to first raise it slightly by turning the crank in the proper direction sufficiently to relieve the pawl. While holding it in this position seize the brake lever with one hand and apply the brake. Then, holding the brake firmly, remove the hand from the crank and with this hand throw the pawl out of the way of the gear teeth. Afterwards slide the crankshaft lengthwise, so as to disengage the pinion from the gear teeth and use the brake for lowering. After the car is stopped at the lower level, the pawl is again thrown against the gear. Before hoisting again, the crankshaft must be moved lengthwise until the pinion engages with the gear. The reason for throwing the gear and pinion out of mesh when lowering is to remove the danger of accident inherent in the rapidly revolving crank. Slipping the pinion and gear out of mesh allows the crank to remain at rest while lowering. A lock or clutch on the frame of the winch may be used to keep the crankshaft in the proper position during raising or lowering.

The pawl must not be thrown into gear while the platform is moving downward, for under such conditions it will break the gear teeth. The form and arrangement of the crankshaft, collar, and gear-shaft lock will be clearly understood by reference to Fig. 27.

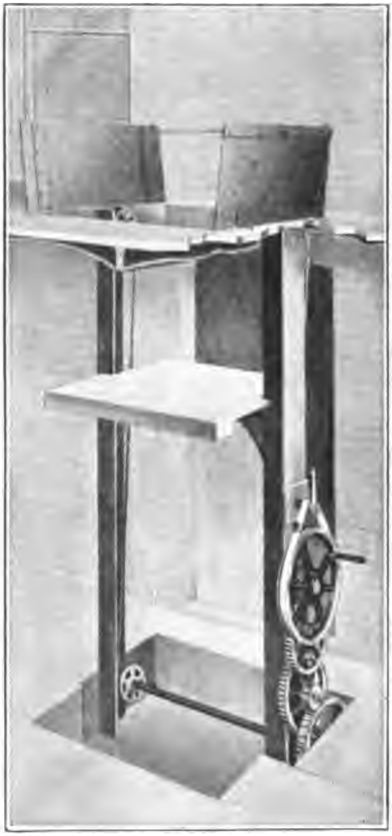


Fig. 28. Two-Cable Basement Elevator
Courtesy of Warsaw Elevator Company, Warsaw, New York

Two-Cable Type. A simple form of the basement elevator or sidewalk lift, suitable only for light loads, is shown in Fig. 28. It includes a train of gearing and a brake similar to that previously described, but these are all supported on studs located near the bottom of the 6-inch side of a 4- by 6- by $\frac{1}{2}$-inch angle iron, the 4-inch side of which serves as one of the guides for the platform. The other guide consists of a similar angle on the opposite side of car. The platform is lifted by means of two $\frac{1}{2}$-inch wire ropes instead of four chains. These wire ropes are

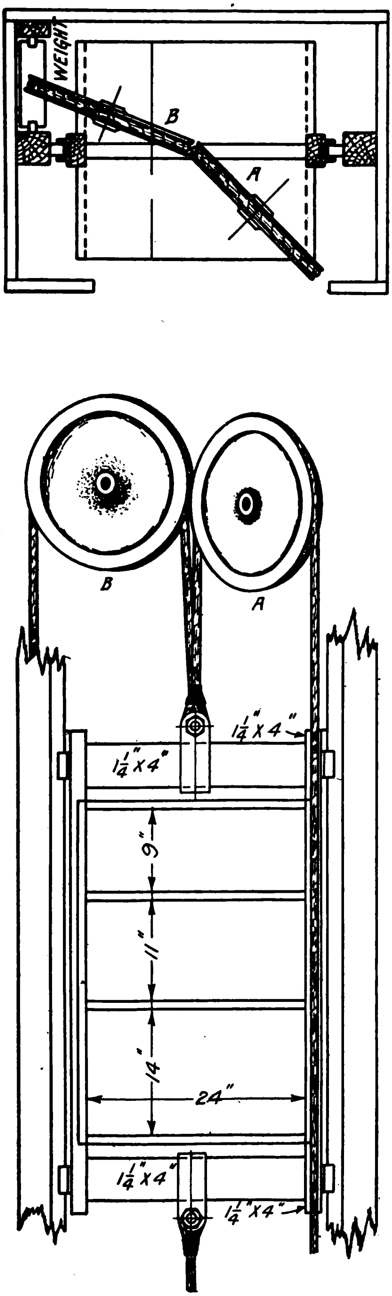


Fig. 29. Details of Domestic Dumb-Waiter

attached at one end to the hoisting drums, which are keyed on a shaft about 2 to $2\frac{3}{16}$ inches in diameter, and are carried up the runway and over two sheaves running on studs attached to the upper ends of the same angle irons, and from there down to the car or platform to which they are attached. The operation of the machine is similar to that of the kind first described, but the entire apparatus is simpler in construction and more easily installed, although not so powerful.

DUMB-WAITER

The dumb-waiter is chiefly used in dwellings, restaurants, and public institutions for the conveyance of food from the kitchen to the dining room, and in stores for sending light packages from one story to another. The loads conveyed vary up to 100 pounds and in exceptional cases up to 150 pounds.

In dwellings the load seldom exceeds 20 to 25 pounds; in restaurants the load may be as great as 40 pounds; in public institutions, such as asylums, hospitals, etc., the loads are often as great as 90 pounds; and in stores the capacity required sometimes reaches 125 pounds.

The machine comprises a box with shelves so built as to have one or two open sides, the number depending on the layout of the building. This box travels on hardwood guides extending the entire length of the run, or travel, of the dumb-waiter. These guides are usually one inch square but vary in types of different make. The mechanism used for their operation differs somewhat according to the service they are to perform and the ideas of the manufacturer.

Domestic Type. Fig. 29 shows the general construction and dimensions of a well-constructed and popular type suitable only for light domestic service.

Box Construction. The box may be made of $\frac{7}{8}$- or $1\frac{1}{8}$-inch pine, fir, or hardwood, mounted on a $1\frac{1}{4}$- by 4-inch carrying frame consisting of two uprights to which the four guide shoes are attached, and an upper and lower crossbeam, the ends of which are mortised and pinned to the uprights.

Tackle. To the center of the upper beam a $\frac{3}{4}$-inch manila rope is attached by passing it around the crossbeam and either splicing it or seizing it. This rope is carried to the top of the run and passed over a sheave *A*, hung in a diagonal position, so as to lead the rope down near the right-hand corner of the box, as shown in the plan view. It is then led down and passed around another sheave set in a similar position near the bottom of the run, and thence up to the lower beam of the box, where it is fastened. A $\frac{1}{2}$-inch manila rope is also attached to the upper beam of the box and is led over the sheave *B* and attached to the counterbalance weight, the position of which may be seen in Fig. 29. This weight, which must not be heavier than the box, runs on hardwood guides about $\frac{3}{4}$ inch square. The $\frac{3}{4}$-inch rope which lifts the box is intended to be used also as a hand rope for operating it, and it is for this reason that it is led down near one of the front corners of the box. It can be readily seen that by pulling the rope in one direction the box will be caused to move in the opposite direction. With such an arrangement a force equal to the load to be lifted plus the friction must be exerted, and, in order to reduce the friction to a minimum, the wood or cast-iron sheaves are often mounted on patent bushings, which are simply small roller bearings.

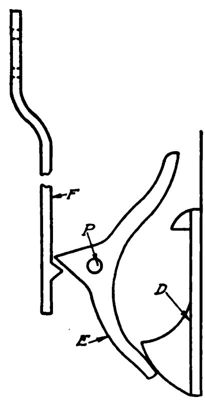


Fig. 30. Box Locking Device for Dumb-Waiter

Box-Locking Device. Fig. 30 shows the box-locking device employed. It comprises a cast-iron cam *D* screwed firmly to the box

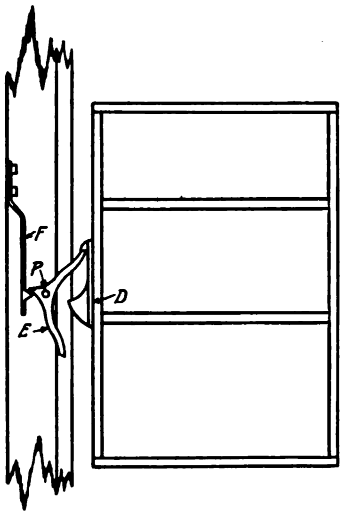


Fig. 31. Dumb-Waiter Locked in Position

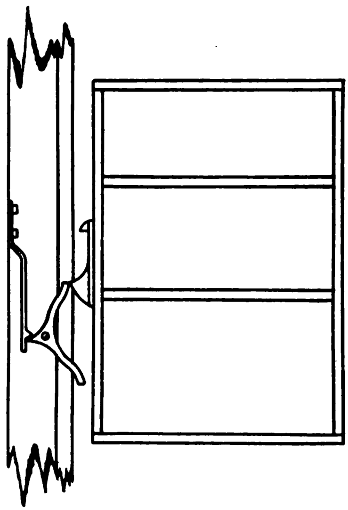


Fig. 32. Position of Lock on Slightly Raising Car

and a cast-iron latch *E* attached in the runway which vibrates on a pin. *F* is a steel spring for holding the latch firmly in position when the box is brought to rest from either direction of movement. A separate latch and spring are required for every doorway in the run.

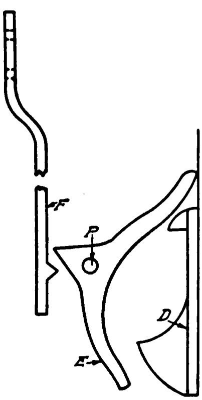


Fig. 33. Cam Position with Car Going Up Just Before Locking

When the latch and cam are in the position shown in Fig. 31 the box cannot descend. To lower the box it is first slightly raised by pulling down on the hand rope until in the position shown in Fig. 32, after which it can be lowered without obstruction.

When a loaded box is to be hoisted to any particular doorway to be unloaded, the box is pulled up until the cam *D* is in the position shown in Fig. 33 and, on being raised an inch or two higher, the top part of the latch will engage with the upper part of the cam, as shown in Fig. 31, and the box will then stand where left. A study of these sketches show that it is impossible, when the parts of this appliance are properly proportioned, for the box to be accidentally stopped while moving in either direction.

Medium-Load Type. Fig. 34 shows the same dumb-waiter arranged with a double purchase to enable the operator to lift heavier loads. The general arrangement is similar to that in Fig. 29, except that extra sheaves are attached to the upper and lower beams of the box by means of wrought-iron straps C and C_1. These straps are made of 2- by $\frac{3}{16}$-inch strap iron bent to fit the beams to which they are fastened by bolts. The sheaves are slipped between the prongs of the forks thus formed and run upon pins fitted into the ends of the straps. The lifting rope is passed around each sheave and the ends are attached to some fixed points in the elevator runway. The effect of this arrangement is to cause the box to travel only one-half the distance the hand rope is pulled, but it gives the operator double lifting power. A car-locking device of the nature previously described is employed.

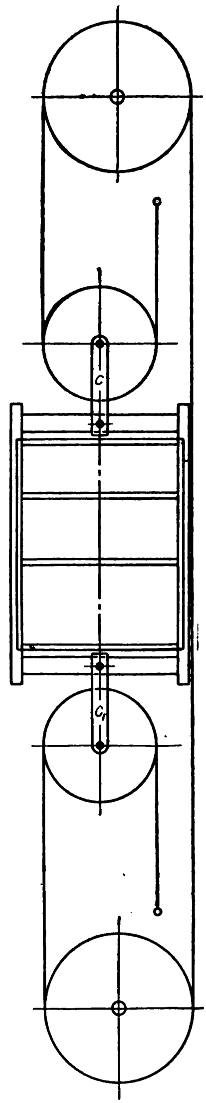


Fig. 34. Details of Medium-Load Dumb-Waiter with Extra Sheaves

Heavy-Service Type. Fig. 35 shows another form of dumb-waiter which is used for lifting heavier loads, such as are common in stores, public institutions, etc. It employs two sheaves of different diameters mounted on a shaft running in bearings. The upper portion of the figure gives two views of the sheaves and shaft. It will be noticed that the purchase is obtained by using sheaves of different diameters. The usual dumb-waiter box and counterpoise weight running on their respective guides are employed. Two separate ropes are used, one being an endless hand or operating rope, which runs in guides the same as the hand rope for a hand-power elevator, and the other being a lifting rope, one end of which is attached to the box and the other to the counterpoise weight.

When the hoisting sheave is not large enough to span the distance from the center of the runway to the plane of movement of the counterpoise weight, it is usual to use two idle sheaves to deflect the lifting rope, these being arranged as shown in Fig. 36, so that the lifting rope is in contact with half the circumference of the lifting sheave, which is necessary in order to obtain the required amount of friction.

Sheave-Locking Device. The most interesting feature of the heavy-service machine is that it will stand wherever it is left, either

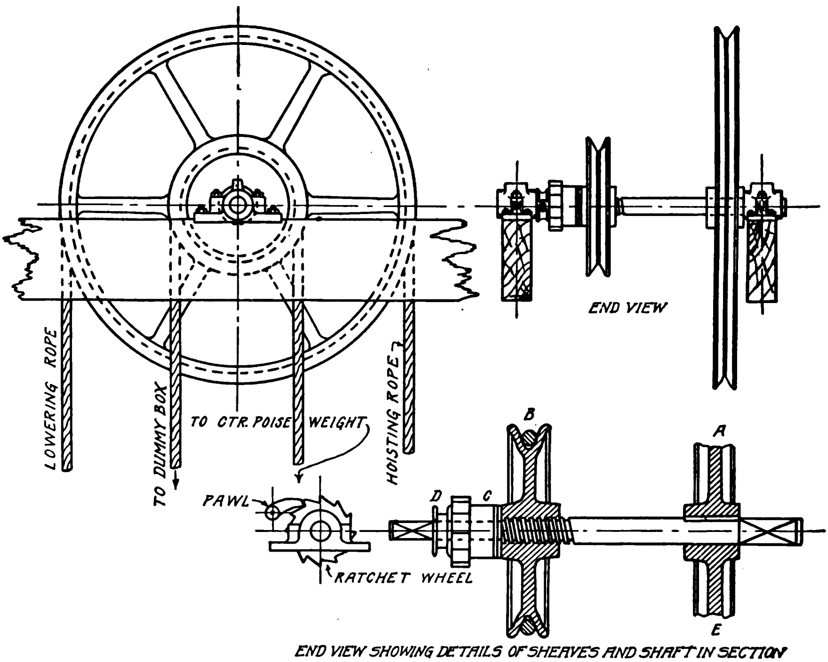


Fig. 35. Hoisting and Driving Details for Heavy-Service Dumb-Waiter, Showing Locking Device

loaded or unloaded. The manner of accomplishing this is quite ingenious, as can be seen in the lower portion of Fig. 35, where a sectional view of a portion of the hand-rope sheave, the shaft, and the hoist sheave is given.

By reference to this figure it will be seen that the hand-rope sheave *A* is keyed solidly on the shaft, but that the inside surface of the hub of the hoist sheave is threaded, and that a portion of the shaft is threaded to fit the hub of the sheave, an easy fit being made, so that the sheave will never stick or jam.

On the plain portion of the shaft beyond the thread is fitted a collar *C*, which is free to revolve on the shaft. This collar has on its periphery a series of saw-like ratchet teeth. When the shaft is in place in its bearings a pawl or dog attached to the framework falls by gravity into these teeth, thus permitting this loose collar to revolve only in one direction. Beyond this loose collar is fitted another collar *D*, which is held rigidly in position by either one or more set screws or by a pin passing through the shaft and collar.

Its manner of operation is as follows: The shaft being in its place in the frame and a load being placed in the box, which is hung from the rope at *B*, the tendency of this load will be to jam the sheave up tight against *C*, which, in turn being kept from revolving in that

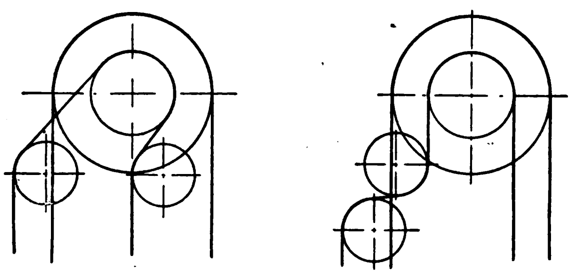


Fig. 36. Diagram Showing the Use of Idle Sheaves to Control Position of Lifting Rope

direction by the pawl engaging in the ratchet teeth on its rim, remains stationary.

In order to hoist the load, it will be necessary to pull down on the *E* side of the hand rope. This action also screws the hoist sheave tight against the collar *C*, and it in turn against *D*, but the action of the pawl on the ratchet permits the revolution of collar *C* in the direction for hoisting and, whenever the action on the hand rope stops, the box becomes and remains stationary.

Lowering the load is done by pulling down on the *A* side of the hand rope, the effect being to screw the sheave *B* slightly away from *C*. This allows *C* to revolve freely on the shaft, and consequently the load will descend as long as the motion of the hand rope is continued, but, as soon as this motion stops, the sheave *B* will become jammed tight against the collar *C* and all motion will cease.

BELT-POWER ELEVATORS

Types. Elevators operated or driven by leather belts first utilized factory-line shafting as a source of power. They may be classified as either spur- or worm-geared. In making this statement it is done advisedly, for, while there are doubtless others, it is safe to say that these two types are the most common and that other types are usually isolated cases. Both types of machines are made for floor and ceiling mounting, and may be located in the basement or at any story of a building.

SPUR-GEARED MACHINES

The spur-geared machine, as can be seen in Fig. 37, is simply a train of spur gears and pinions having pulleys for leather belts on

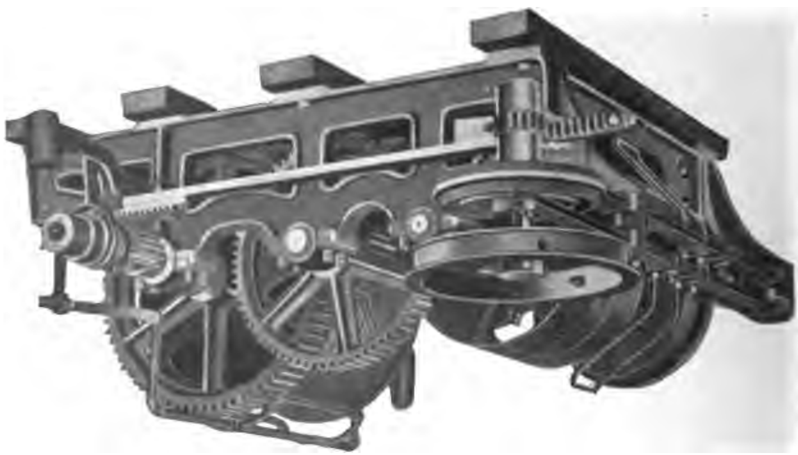


Fig. 37. Ceiling Type of Spur-Geared Belt-Power Elevator

the first shaft and a spirally grooved spool or drum for winding up the hoist rope on the last shaft. A middle or intermediate shaft is not absolutely essential but is used for convenience. By its use smaller spur gears may be used on the drumshaft, and the whole machine may then be made less cumbersome.

Gearing. These three shafts have journals at each end. These run in pillow blocks or in babbitted bearings usually cast in one piece with the side frames which serve as the support of the entire machine. The pinion, which is keyed on the first or pulley shaft, and the gear on the intermediate shaft are cut gears; that is, they have their teeth formed in the gear cutter because the speed at which they run makes this neccessary in order to reduce the noise in operation, as well as to lessen the vibration which would ensue from the use of rough-cast gears. To further insure the safety and life of the machine, the pinion on the pulley shaft should be cut from a cylindrical piece of wrought mild steel which has been previously bored in the lathe to fit the pulley shaft.

The cut gear is keyed securely on the intermediate shaft, and alongside it is keyed a cast pinion having about 14 or 15 teeth, $1\frac{1}{4}$-inch pitch, and 4-inch face. This pinion in turn drives a gear having about 75 teeth, which is keyed on the drumshaft as well as bolted to the drum. The diameters of the shafts are as follows: first or pulley shaft $2\frac{5}{16}$ inches, intermediate shaft $2\frac{7}{16}$ or $2\frac{9}{16}$ inches, drumshaft $3\frac{3}{16}$ inches or $3\frac{7}{16}$ inches, as convenient to obtain. When the gear is bolted to the drum, it relieves the drum shaft of torsional or twisting strain.

Pulleys. The pulleys used for a machine of this capacity can be 20 to 22 inches in diameter and suitable for 4- to 5-inch belts, according to the load it is desired to lift, whether it be 2000 or 3000 pounds. Three pulleys are employed, two of them being idlers or loose pulleys, and the middle one a tight pulley, that is, keyed firmly to the pulley shaft. The loose pulleys are usually bushed with bronze sleeves and are always provided with compression grease cups to properly lubricate them. These pulleys are kept in place against the hub of the tight pulley by collars and set screws. Each shaft is provided also with collars to run against the ends of the pillow blocks to prevent end motion in the shafts.

Belts. The machine is driven by two leather belts from a "straight-faced" pulley on a line or countershaft. The width of the face of this pulley is equal to the combined width of the two loose and one tight pulleys on the machine. One of the leather belts is an open one and the other a cross belt for the purpose of obtaining reverse motions. The diameter of the pulley on the line depends on the speed of the line or countershaft, but it should be of a diameter capable of producing the speed desired at the machine. For example, suppose the winding drum is 30 inches in diameter, or 94 inches in circumference, and the desired speed of platform 50 feet per minute. About 6.4 turns of the drum per minute would be required to develop this speed. Now the ratio of the gears and pinions is respectively 6 to 1 and 5 to 1, making the ratio between the first pinion and last gear 30. Hence the pulleys on the machine must revolve at the rate of 30 times 6.4, or 192 revolutions per minute.

Belt Shipper. The motion of the tight pulley in either direction is obtained by shifting, or "shipping", one or the other of the belts on to the tight pulley by means of the belt-shipping device, comprising two shipper bars fitted with belt forks or belt shippers and operated independently of each other by a cam movement, which will be discussed separately at the proper time. This cam movement is so arranged that when it ships both belts onto their respective loose pulleys, it simultaneously applies a powerful brake either to the tight pulley on the pulley shaft or to another special pulley on the same shaft. When the cam is moved to ship either belt onto the tight pulley to start the machine, it releases this brake, but not until the belt has a firm grip on the tight pulley, for here is the danger point in the spur-gear machine. This danger is greater when the lowering belt is shipped onto the tight pulley. Should the brake be released a moment too soon in starting, or too tardy in stopping, a sudden drop of a foot or two at the platform will result, especially if the load on the car is heavy.

The reason why the car or platform drops only a foot, or at the most two, before it recovers its self-control is due to the continued motion of the belt shipper after the operation of starting the elevator is begun. Should the movement of the belt shipper cease at this critical time, there will be nothing to prevent the car running rapidly down to the lowest point of its travel. Of course, the sudden arrest of the descent of the car by the belt being shipped over onto the tight pulley far enough to control it throws a great strain on the belt, which has been known to part, thus allowing the car to rush rapidly down to the lower end of the run.

Centrifugal Safety Devices. *Pulley Governor.* In order to provide a safety speed control the centrifugal governor, as shown in Fig. 38, was devised. The centrifugal governor includes a case or box of circular shape turned true on the inside and bolted to one of the side frames of the machine so as to be central and square with the pulley shaft, which is made long enough to reach almost through this case. A spider, or hub with arms, to which are pivoted levers or weights, is also used. These weighted levers are provided with rubbing shoes, usually faced with either leather or hard maple, to rub on the inside of the rim of the box or shell case. The levers are held back from rubbing on the shell by springs, the tension of which is adjusted to the speed at which the pulley shaft is to run. Any increase of speed beyond the normal tends to throw the shoes against the sides of the case, producing friction which retards the motion of

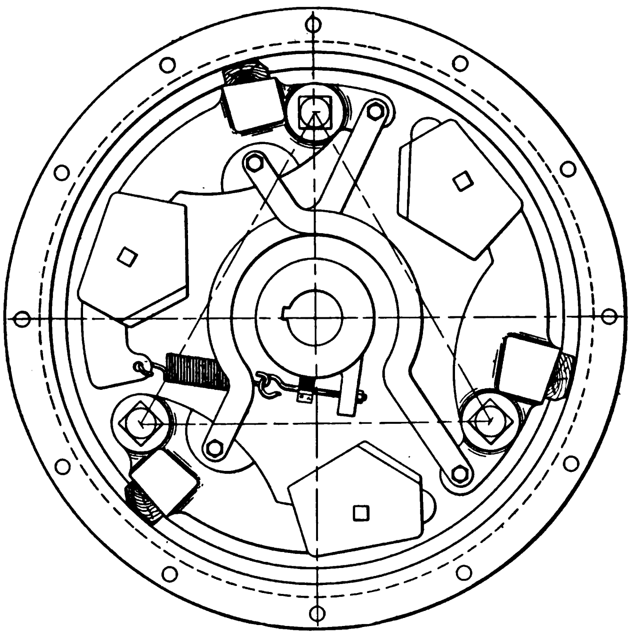


Fig. 38. Side View of Pulley-Type of Governor

the machine but does not stop it, thereby permitting the car to run ¯¬wn but not as quickly as without the governor.

` *Governor.* One of the oldest and a good form of governor 40, 41,' Fig. 39. It comprised a winding drum placed overhead and floo ¬y in place of the top or overhead sheaves generally in a cast-. cables from the winding machine to the car. This is used to ι with spiral grooves to receive the cables. Two receptacle ι ' One was fastened to the drum on the winding a constant anι ˀ drum over the hatchway, where the other end universally placeι ɘr cable led from this overhead drum down to the car, the ends of the cable being attached to the drum and the car. The length of the first cable had to be sufficient to reach from the drum on the machine up to the overhead drum and around the latter as many times as were equal to the travel of the car, plus a few spare turns on each drum. The length of the other cable was from the overhead drum down to the top of the car, when in position at the lowest landing, plus two or three turns around the drum.

The drum at the top of the hatchway had cast on the end of it a very broad band or pulley *A*, which was turned true and smooth

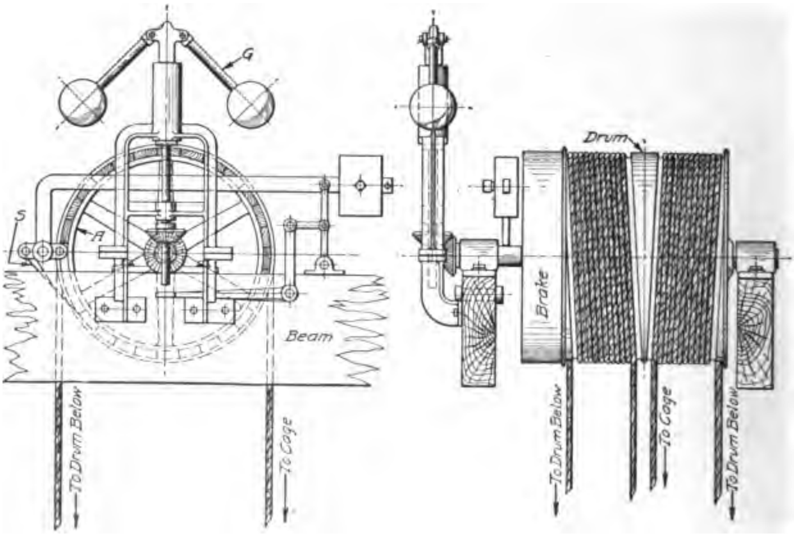


Fig. 39. Side and End View of Drum-Type of Governor

in the lathe. Around it was bent a band of steel *S*, lined on the inside with blocks of maple and fitted with a powerful wrought-iron lever. at the end of which was a heavy cast-iron weight. The whole a- ratus formed a very powerful brake. Instead of a cam ler to pro- to release the brake or apply it, it was held inoperativ wn in Fig. of a bolt or catch which, when the lever was raised, k case or box the brake being off when in that position. to one of the

On the end of the drum shaft was a miter gear, quare with the similar gear on the frame of a two-armed gover almost through spindle of which, instead of opening and closin h are pivoted levers case the drum revolved at an abnormal speed, release the bolt and allow the lever and weight to drop, thus applying the brake.

When the hoisting belt was shipped on to the tight pulley, the drum or the winding machine commenced to wind up the cable connected to the upper drum which, being already wound on that one, would in the process of unreeling cause it to revolve. It in turn wound up the cable attached to the car, thus hoisting it up the hatchway, and *vice versa*. If, when the motion was changed for lowering, the cable between the upper and lower drum should break, the quick descent of the car would cause the upper drum to revolve fast enough to make the governor trip the bolt and let the lever drop and apply the brake.

This safety device, however, had the defect of being incomplete, inasmuch as it was operative only in case of a rundown owing to a broken or imperfectly shipped belt, or when the cable between the drums parted, but not when the cable from the drum to the car broke. This latter contingency was provided for by the use of safety dogs on the car, which were actuated by a spring.

This safety device has been described in detail because it was at one time considered one of the best in use, and because it was the forerunner of the modern type of governor safety. This form of safety was introduced somewhere around 1864 or 1866, when power elevators were in their infancy.

Undesirable Features. The difficulty of obtaining a suitable safety device with spur-gear elevators is the strongest objection to this type of machine. This, combined with the fact that the operation of such a machine is noisy, often overweighs the fact that this type of machine is at least 85 per cent efficient.

WORM-GEARED MACHINES

General Design. Turning now to worm-gear apparatus, Figs. 40, 41, and 42 give a general idea of the appearance of the ceiling and floor types of this winding machine. The gearing is enclosed in a cast-iron box or casing, usually termed the shell. This casing is used to confine the oil used for lubrication, and also to serve as a receptacle or reservoir for it, as this form of gearing requires a constant and very liberal application of oil. The worm is almost universally placed below the gear, partly because the machines are hung to the under side of the floor joists on cleats similar to the way shafting is hung, but mainly so as to allow the worm to run immersed in oil.

Parts and Their Mountings. The apparatus consists of the worm, which is simply a short screw of coarse pitch, with the shaft usually an integral part of it; a toothed gear in which the worm runs; and a shaft to which the gear is keyed firmly. This shaft is made long enough to extend through the bearings in the shell or casing, and also to allow the keying on one end of the drum or spool on which the hoisting rope or cable is wound and the placing of a journal beyond

Fig. 40. Typical Ceiling Type of Worm-Geared Belt Elevator with Plate-Cam Belt Shipper

the drum for support. This shaft is called the "drum shaft". A hanger with babbitted bearing, or box, for the outer end of the drum shaft to run in is provided, being either cast on or bolted to the shell or gear casing. The bearings for both the worm and drum shafts are provided with pads or patches to which are bolted the attachments for the limit stops, the belt shippers, two loose pulleys and one tight pulley, the usual belt-shipping apparatus, the automatic or limit stops, and a hanger for the support of the outer end of the worm shaft.

Operation. In order that the student may obtain a clear understanding of the operation of the worm and gear, a section of the shell or housing is given in Fig. 43. When the worm, which is shown in cross section, is caused to revolve on its axis, the spiral thread pro-

Fig. 41. Floor Type of Worm-Geared Machine with Cylindrical-Cam Belt Shipper

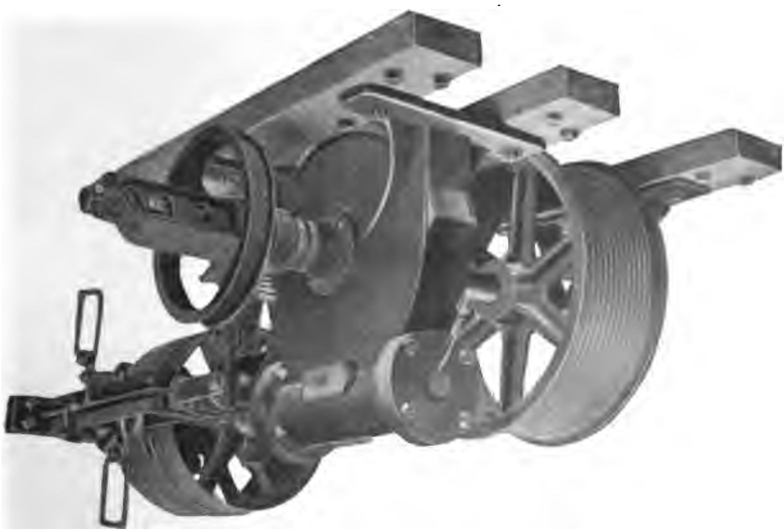


Fig. 42. Ceiling Type Worm-Geared Machine

duces an endwise motion similar to that of a screw in a nut; but, as the worm is prevented by its bearings from moving endwise, it transmits that motion to the teeth of the gear and causes it to revolve.

This motion is transmitted through the drum shaft to the drum, which winds and unwinds the hoist cables.

End Thrust on Worm Shaft. It is obvious that a heavy load on the hoisting rope will produce an intense pressure endwise on the threads of the worm, that is, endwise on the worm shaft. To illustrate, let us suppose that a load of 2000 pounds is being lifted, and that the drum is 30 inches in diameter and the worm gear 24 inches at the pitch line. Then the end thrust of the worm shaft will be $\frac{2000 \times 30}{24}$ or 2500 pounds. The dimensions given for gear and drum are about what are used in general practice, the drum being always

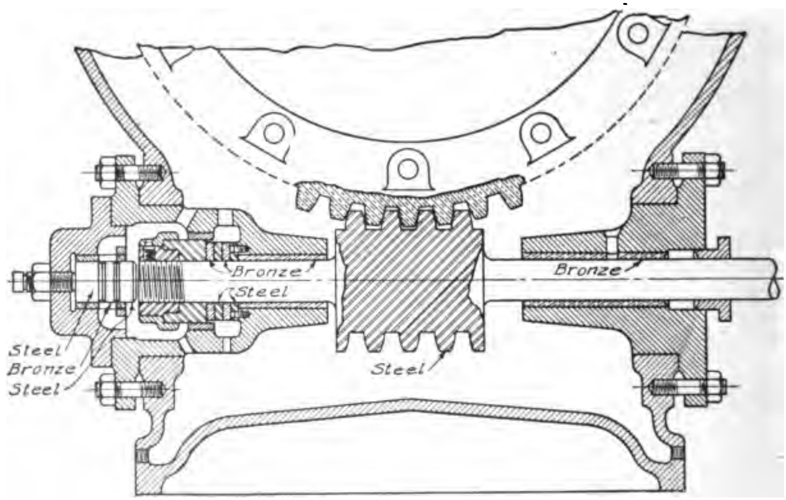


Fig. 43. Section through Worm-Gear Housing, Showing End-Thrust Arrangement

larger in diameter than the gear. This end thrust on the worm shaft is taken care of by means of what are called thrust buttons, which will be described later under the discussion of the worm and gear.

Desirable Features. *Locking Action.* The greatest advantage of using worm-geared machinery for elevator drive lies in the fact that, although the worm and gear unit permits motion to be transmitted from the worm to the gear, it does not permit motion to be transmitted from the gear to the worm. Hence worm-gear machinery is self-locking, for, since the winding drum is connected to the worm gear, it is impossible for any change in load on the car to cause movement, because to do so the gear would have to be capable of producing motion of the worm. This feature is a very desirable one, because it means that no car-locking device is required, for the car cannot descend as the result of any load being placed upon it.

Undesirable Features. *Friction.* The spur gear, it will be remembered, generally consumes in friction less than 15 per cent of the energy supplied it; but a badly proportioned worm and gear may waste in friction as much as 50 per cent of the energy supplied, and will therefore be only 50 per cent efficient. But a well-proportioned worm and gear is not so uneconomical as this, for gears can be so built as to consume in friction 30 per cent or less of the energy supplied them.

Worm-Shaft Speed and Pressure. Reference to Fig. 43 will show that one revolution of the worm shaft will only cause the worm gear to move through the space of one tooth, while one revolution of the pinion of a spur-geared machine will cause the spur gear to move through as much space as is occupied by the same number of teeth as are on the pinion. Assuming, as was done in the case of the spur-geared machine, that the winding drum is 94 inches in circumference, and that a car movement of 50 feet per minute is desired, it will be found, if a worm gear having 50 teeth is employed, that the drum will make approximately 6.4 turns per minute, and that the worm shaft will have to revolve at the rate of 6.4×50, or 320 revolutions per minute, as required under the assumptions made in the case of the spur gear.

Mention has already been made of the large-end thrust on the worm-gear shaft. This also means that there is a large tooth pressure greatly in excess of that common with spur gears used for the same purpose.

PRIME MOVERS

Use of Separate Prime Movers. Although these belted machines were originally built to meet the requirements of an elevator operated from a line of shafting in a factory, it later became apparent that there were many cases where, owing to the absence of power machinery, an engine would have to be employed for the sole purpose of operating the elevator. In such cases a steam engine, gas engine, or electric motor may be used.

Steam Engine. When a steam engine is employed it must be of ample power, that is, one rated at 150 to 200 per cent of the actual horsepower required. In all cases where the engine is to drive the elevator as its only, or as its principal load, the precaution must be taken to use a flywheel twice as heavy as would be required by the same engine when running constantly under a full or nearly full load. The reason for this is that the work of an engine driving an elevator exclusively fluctuates to such a degree that no governor has ever been made which can take care of the engine under such extremes.

For example, let us suppose that the engine is running with the elevator at rest. In this condition the engine is driving only the countershaft and pulleys to which the elevator apparatus is belted, the power delivering probably not more than one and one-half to two horsepower. In the meantime the elevator, having been fully loaded, is started; that is, the hoisting belt is shipped onto the tight pulley, an operation occupying not more than two seconds of time. Now, if the load requires eight horsepower to lift it, the engine is suddenly called upon for eight additional horsepower, with the result that the engine nearly stalls or stops until the governor opens up the valve and the engine takes steam and gradually recovers speed. However, in the meantime the elevator will have run nearly a story. When the car arrives at the stopping place and the belt is shipped back onto the tight pulley, the engine races for a few seconds until the governor has time to act. This kind of service is, of course, unsatisfactory, but it may be easily avoided by following the recommendation of having an engine of ample capacity equipped with a heavy flywheel.

Gas Engine. The trouble just mentioned is especially serious with gas or gasoline engines. This kind of engine rarely develops the full rated power and it cannot recover itself as quickly as a steam engine because it has to take in a charge of gas and air and compress it before an explosion can occur. Thus a gas engine is more liable to stop under these severe conditions than a steam engine. However, by installing an engine with a capacity of 150 to 200 per cent of the horsepower required and adding a flywheel of double the usual size no inconvenience will be experienced.

Electric Motors. *Non-Reversible Type.* In the case of driving the elevator with an electric motor no trouble of this kind will be experienced if the motor is shunt wound and greater than the capacity required; but should the motor size be close to the actual horsepower required, lowering with a full load, especially if the elevator be of the spur-gear type, may cause the motor to race. In fact, unless the field of the motor is ample for its horsepower, the motor will be driven by the elevator at from 10 to 30 per cent above its normal speed, with the result that the motor will act as a generator. Hence, the obvious and most simple remedy in cases of this kind is to use a motor of ample horsepower and with properly proportioned fields both as regards volume of core iron and field copper.

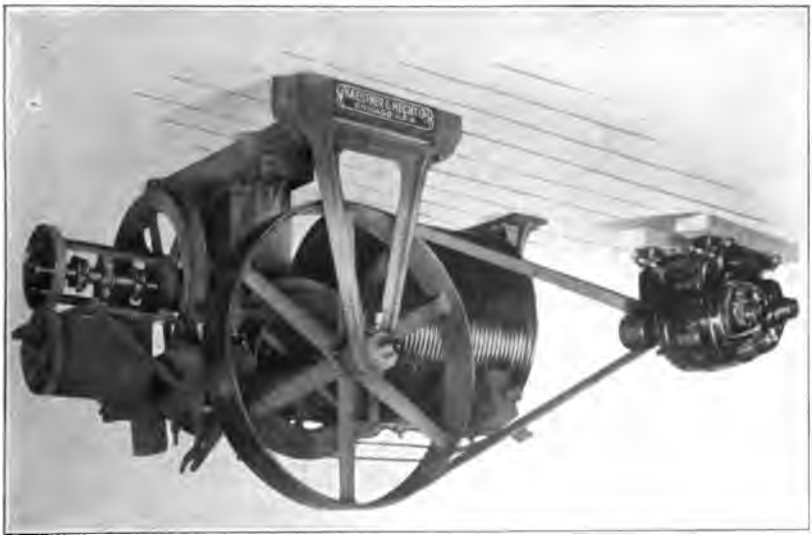


Fig. 44. Reversible Motor Drive for Belt Elevator
Courtesy of Kaestner and Hecht, Chicago, Illinois

In the case of a motor driving a countershaft a flywheel is of ro benefit, as its momentum accelerates rather than retards the speed of the motor. Short-circuiting the armature through resistance coils will produce very satisfactory results, but the difficulty surrounding its application to this particular type of machine makes it impracticable.

Reversible Type. The belt elevator is sometimes driven by a reversible motor, which, although high in initial cost, possesses many advantages over the motor-driven countershaft and reversing-belt method. In such cases a compound-wound reversible motor is used with a controller, Fig. 44. The hoisting apparatus is driven by a belt and pulley from the motor, which is hung to the joists in line with the hoisting apparatus. The motor is attached to a sliding base so that, as the belt stretches, the motor can by means of screws be moved to take up the slack in the belt. Such an elevator is called a single-belt machine to distinguish it from those using two belts and a belt shipper to obtain reverse motion.

In this type of machine the entire operation of the elevator is accomplished by stopping, starting, and reversing the motor by means of the controller, which is also provided with a mechanical connection for releasing and applying the brake. In some few cases the brake is applied by a powerful spring and released by an electrical connection which energizes a solenoid properly attached for the purpose, but this form of brake is not used extensively with the single-belt elevator. Braking action can also be obtained by short-circuiting the motor armature, as will be described in the discussion of modern electric-elevator control.

SAFETY DEVICES

Center Line. Every freight elevator, especially those operated indiscriminately by anyone who needs the elevator for the time being, should be provided with a center line, which will be described later. In the hands of the unskillful operator it is essentially a safety device as well as a convenience. The operator has only to remember that to stop the elevator he must pull the center line until the car stops.

Slack-Cable Stop. The striker, which is part of the automatic stop, is a wrought-iron arm attached to the car having an eye encircling the operating cable and moving with the car during its entire travel in either direction. At each end of the run, a knob of cast iron called a stop button (see Fig. 81, Part II) is affixed to the operating cable, which should always be so arranged as to make a down pull on the rope correspond to an upward movement of the car, and *vice versa*. The button is made in halves, with a properly formed groove to fit over the cable, and is clamped tightly on the cable by means of bolts. The striker arm in traveling with the car will pull the operating cable back to its former position and thereby stop the elevator on meeting with an obstruction in the form of the stop button.. It is, in fact, an auxiliary limit stop and, if it is set properly, should stop the elevator of itself a little in advance of the automatic limit stop, which will be described later. It thus saves that valuable and useful device from wear and tear, leaving it in fine condition to perform its duties without fail, in case the operating cable breaks or the buttons slip. The student will readily see from this description that this combination really forms a double safety. The slack-cable stop is an attachment designed to stop the elevator instantly in case the cables become disarranged on the drum, and is an appliance which should be on every elevator driven by power.

BELTS AND BELT SHIPPERS

Belts. Leather belts of double thickness and of full width should always be used. Cotton, rubber, or any other belt with a textile fabric for its basis is unfit for use as a shifting belt—that is, one which has to be shipped from one pulley to another. The action of the belt shipper frays the edges of this kind of belt, wears it out, destroys its tractive powers, and soon renders it unserviceable. Moreover, this kind of belt cannot be made endless, and the necessary belt lacings or other fasteners make lumpy joints causing noise and having a bad effect on the machine. Leather belts are stronger, wear better and, although they stretch more at first than the other kinds, can be made endless without impairment as often as they need to be shortened; but they should always be of double thickness and of strictly "back stock", short-lap, and riveted.

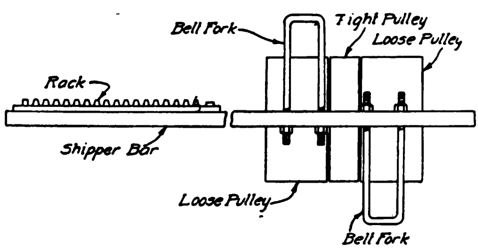


Fig. 45. Early Form of Belt Shipper

Belt Shipper. *Early Type.* In the first power elevators the belts were shipped or shifted from the loose to the tight pulley and the reverse, as shown in Fig. 45, by means of a bar of wood or iron sliding in suitable guides and moved lengthwise by means of a rack bolted to the bar, which was operated by a toothed pinion keyed on a rigidly supported short shaft. On this shaft was also keyed a sheave, around which the operating cable was wrapped two or three times and attached to the sheave at the center portion of the wraps in order to insure its positive movement and at the same time to enable it to turn in either direction. Both belt forks or fingers, as they are termed, were attached to this bar, and it necessarily followed that both belts moved at the same time and together. The form of this device necessitated the use of loose pulleys of double the width of the belt, and, although the arrangement was simple, it was very clumsy in appearance.

Cylindrical and Disk Types. Appliances of this nature were devised later which shipped one belt at a time. A number of different devices were used, but the best and most popular were two in number, and it would be hard to decide which was the better, because each had desirable features not possessed by the other, and each was applicable to situations in which the other was not so convenient.

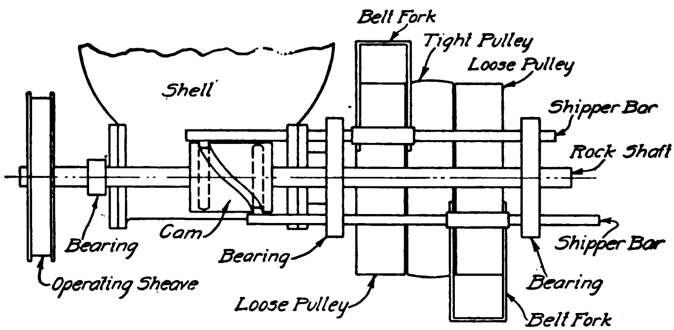


Fig. 46. Details of Cylindrical-Cam Belt Shipper Shown in Fig. 41

Both were fitted with two independent shipper bars equipped with belt forks or fingers, between which the belt was made to travel. When a shipper bar was moved, its belt fingers carried the belt with it. As each shipper bar controlled only one belt, only one belt was moved at a time, the other remaining stationary while its companion was in motion. One of the awkward features of this device was that the shipped belt always had to be returned to its original position before the other could be shipped.

In both cases the operation of the shipper was accomplished by a cam. In one case the cam was a cylinder, Fig. 46, having a helix cast on its surface in the form of a groove into which a pin and roller worked. This is shown mounted in Fig. 41. Each end of this helical groove was deflected from its spiral course and was made to run at right angles with the axis on which the cylinder revolved. The pins and rollers on the ends of the shipper bars were so arranged and set that when the belts were running on their respective loose pulleys, these pins were at either end of the helical groove. It is evident that if the cam were made to revolve in either direction, one pin would be caused to run in the helix while the pin on the other shipper bar would run in that part of the cam or groove which was at right angles with the axis. The pin running in the helix would be caused to traverse the length of the cam carrying with it the shipper bar, while the pin running in the groove at right angles to the axis would remain stationary.

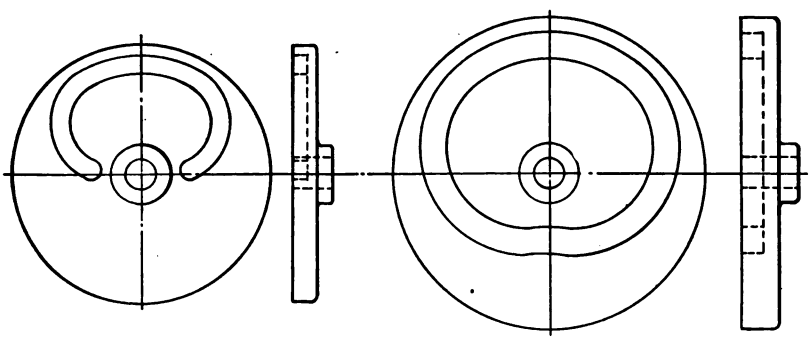


Fig. 47. Details of Plate Cams for Belt Shipper, Shown in Figs. 40 and 42

The other type of cam was a flat circular plate, having in it a groove or channel for the movement of the pins, Fig. 47. A portion of this groove was concentric with the axis on which the plate revolved, but at either end the curve approached the center of the plate, as shown. The device is also shown mounted in machines in Figs. 40, 42, and 48. Pins which were set in this groove in proper position would be moved in a manner similar to that described above.

Braking Means. A feature common to all three types was a cam for applying the brake. It was so shaped and arranged that, when the belts were both shifted to the loose pulleys, the brake cam pressed directly against the brake shoe or against the end of the brake lever to which the shoe was fixed. This caused the shoe, which was of cast iron and lined with sole leather, to press hard upon the tight pulley.

Some makers use a separate pulley for braking, though no

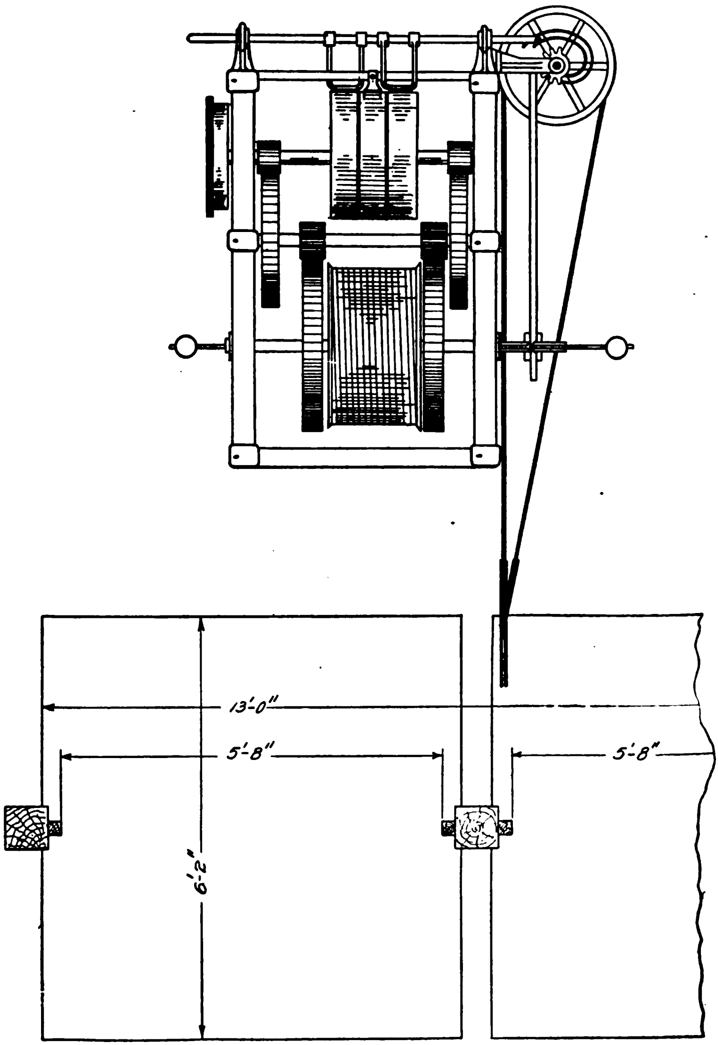


Fig. 48. Diagram Showing Application of Plate-Cam Belt Shipper

special advantage is gained by this except that with the independent pulley a brake band may be used, the latter arrangement being inapplicable to the tight pulley of the machine.

WORM AND GEAR

Historical. Among the various forms of gearing used for the transmission of power, none is so little understood by those making and using them as the worm and gear. It may safely be said that, until the advent of the power elevator, about 1862 or 1863, the application of this form of gearing for use under great stress, and at what was then considered high speeds, had not been attempted on any large scale, and that its performance was not very satisfactory.

This was due to two or three reasons. One was the use of unsuitable materials in the construction, another was a lack of knowledge of the correct proportions of the members comprising this combination. Strange as it may seem, the very first attempts at its use were more successful than the efforts for improvement made later. This was due to the conditions attending both its production and use.

PERIOD OF DEVELOPMENT

EARLY TYPES

Wrought-Iron Worms. The first worms used for elevator service were made of wrought iron, owing to the fact that they were more easily produced in this way. In order that there might be no uncertainty about the strength and solidity of the threads, the quality of iron used was of the best. The worms were usually made by welding bands or rings of Swedish iron around a piece of shafting iron at the place where the worm threads were to be located. The whole was then put in the lathe and turned and the worm cut out of the solid forging at the place where the rings had been welded on. The use of Norwegian or Swedish iron was to prevent the possibility of there being faulty places in the threads of the worm—a condition which would impair its usefulness. The result was usually a clean, bright, close-grained worm of even texture and small diameter, all desirable qualities.

Gear. The gear was made of cast iron. In many cases it was made like an ordinary spur gear, but with the teeth set at an angle across its face to correspond with the angle of the threads of the worm. However, it was found this form of gear was not so lasting as another form made with a concave face. The latter form had the advantage of presenting a greater surface to the worm and, as a result, was found to last longer and to be more efficient.

Cast-Steel Worms. Later, when steel cast ings came into use, many elevator makers began to experiment with worms made of steel castings, the threads being cast on the worm. The worm was then bored to fit the shaft and, after being keyed thereon, was turned, the threads being trued up in the lathe. In fact, before this time some experiments had been made with cast-iron worms, but it was found that a worm and gear both made of this metal did not work well together, although in some cases during the early stages of their use, where a smooth surface was obtained, the results were very satisfactory. In these isolated cases it was found that their satisfactory use was due largely to the kind of lubricant used, the lightness of the loads lifted, and possibly also to the closeness of the grain in the iron of which the worm was made. In general, however, the cast worm was not a success, but it did demonstrate the fact that the diameter and pitch of the worm had more to do with its successful operation than had been suppposed.

CORRECT THREAD ANGLE

Relation Between Thread Angle and Worm Diameter. The first worms—those made by forging—were rarely more than 4¼ inches in outside diameter, or 3¼ inches at the pitch line, and of 1½ inches pitch. Cast worms used on a shaft of the same diameter as the forged worms were made of 5 and even 6 inches outside diameter, or 4 to 5 inches at pitch line, owing to the necessity of leaving sufficient stock around the bore between the shaft and the root of the threads for the keyway. This, of course, changed the angle of the helix or thread as shown in Fig. 49. The outer parallelogram represents the outline of a worm 6 inches in diameter, and the inner parallelogram, of one 4 inches in diameter. The line *A* is the center line or axis of the worm. The line

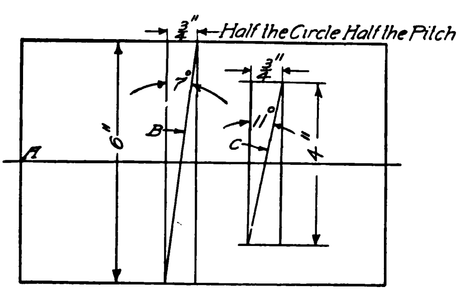


Fig. 49. Variation of Angle of Thread with Worm Diameter, Pitch Constant

B shows the angle of 7 degrees which the thread forms with a line perpendicular to the axis on a 6-inch worm, while line *C* shows the angle of 11 degrees formed by the thread on a worm 4 inches in diameter and of the same pitch. It will be readily seen that the larger the diameter of worm, the smaller the angle between the thread and a line perpendicular to the axis *A* of the worm becomes.

Efforts Decrease Thread Angle. It was thought at this time that a small angle for a worm thread was preferable, because in such a case the thread would be less liable to back down or reverse with a load. So firmly did this idea take hold that it was not considered good practice to use a worm having a thread which made an angle of more than 10 to 12 degrees with the perpendicular to the axis of the worm shaft. As the pitch of worm then used was always 1½ inches, the only way to keep the angle small was to increase the diameter of the worm.

In their efforts to keep the angle small many makers used worms of 7 and even 8 inches diameter with the same pitch of thread and the same diameter of gear, making the face and teeth conform to the increased diameter and to the angle of the larger worm. These, in all cases, failed to give satisfactory results, as increased friction, heating, and cutting developed. While some beneficial results were obtained by varying the lubricant and decreasing the pulley diameter, the general opinion was that a worm of larger diameter than 6 inches was not desirable, although no satisfactory explanation of the fact was obtained.

Development of the Correct Worm Thread. Early in the seventies, William Sellers and Company of Philadelphia, Pennsylvania, manufacturers of machine tools and geared-belted elevators, applied the worm to machine tools with little success. They immediately began to experiment on the subject and made some important developments. These experiments were not made public at once, and in the meantime developments were taking place among the builders of elevators.

Causes of the Developments. The introduction of the gas engine and a frequent demand for higher speed with the belted worm-gear elevator were the principal factors in bringing these developments about. The gas engine very seldom developed its rated horsepower in the early days of its existence, and among the schemes devised to help it was the application of a heavier counterbalance weight. This was attached to the drum in such a way as to pull counter to the car and load. Usually it was made 500 to 600 pounds heavier than the car, and while it certainly helped the engine to lift a heavier load, this extra amount of counterweight had to be raised in lowering the empty car. It was also found beneficial in lowering loads because it assisted in preventing racing or running down; but it was soon discovered that the worm, which set up undue friction or heating, could not be used with a gas engine whose capacity was not in excess of that required. At the same time a demand arose for a fairly speedy passenger elevator which would not be so expensive as either the hydraulic or the steam elevator of those days.

Most Efficient Thread Angle. This led to experiments along the line of increasing the efficiency of the worm and gear, and the investigations then made led to exactly the same results as those made with the planer drives, namely, what is now accepted as a well established fact, that a worm for elevator service gives the best results when it is made of such a diameter and pitch that the angle formed by the thread with the perpendicular to the axis of the worm is from 15 to 20 degrees. It was also learned that the percentage of loss by friction is much less with a worm driven at a high speed, provided the angle of the thread is within the range mentioned or, at least, not below 15 degrees. A greater angle than 20 degrees does not produce any bad results; but at the same time it does not appear to increase the efficiency of the worm to any noticeable extent, while for elevator service it possesses the undesirable feature of not being self-locking, that is, with a heavy load the gear is capable of turning the worm. On the other hand, the worm of from 6 to 10 degrees of angle gives very bad results. Although it must run comparatively slow, and the lubrication must be of the best, the percentage of power wasted is high. Moreover, if the oil used is lacking in body, the lowering of a heavy load with a worm and gear of this description is accompanied by a loud screeching noise, which is very unpleasant, and any increase in speed increases all these troubles.

Double-Thread Worm. Some of the conclusions arrived at were disclosed by the efforts made to run worm-gear machines at a high speed with the worm of low angle. It was then that, in addition to the heating, another trouble developed—that is, the difficulty in stopping the elevator gently with a high belt speed. To overcome this a worm of greater pitch was used. The pitch was increased from $1\frac{1}{2}$ inches to 3 inches, using two threads on the worm instead of one. This scheme retained the original thickness and depth of thread, but increased the angle, and, while it doubled the speed of platform, it did not necessitate an increase of belt speed. It was also noticed that much less power was required to drive the double-thread worm than the single. The stops made at the landings, however, were never satisfactory, owing to the fact that the brake had to be applied harder and more quickly because of the tendency of the worm to reverse as the result of the pressure caused by the load; in other words, by the tendency of the gear to drive the worm.

Value of Experiments. However, the belt-power elevator, upon which these experiments were mainly performed, was destined to be replaced to a large degree by the more modern types. Much of the objection to belt-power elevators lies in the accuracy with which the brakes have to be applied in making a stop. In shifting a belt for this purpose from the tight to the loose pulley, the belt finally reaches a point where there is not enough of it in contact with the tight pulley to control it. It is at this point that the brake must be applied. If the load on the car is heavy, this moment arrives much sooner than it does when the car is being hoisted empty; and in the case of lowering, the critical moment arrives still sooner. However the brake may be timed and adjusted, it will always be applied exactly the same, both as regards the time and force applied to stop and hold. Only at slow speeds is it possible to adjust the belted machine so as to make a gentle stop. Hence the use of the belted elevator as a passenger elevator has not been a success, but the information gained by these experiments has been invaluable, especially in the application of the worm and gear to the electric elevator.

MODERN WORM AND GEAR

During this period, in which the most advantageous angle for the thread was learned, numerous attempts were made to increase the serviceability of gearing. Henry Hindley of New York City introduced a worm which was longitudinally concave, and which was known as the Hindley gear, Fig. 50. Although applied to numerous elevators it was found to be unsuccessful in that form, owing to the excessive friction or braking action which developed with wear.

Introduction of Bronze Gear. Bronze gears used with a forged steel worm were introduced during this period, thus giving us the most successful worm-gear combination of today. Only the rim containing the teeth is made of bronze, a flange usually being provided for bolting it to a cast-iron center forming the hub and web of the gear. Sometimes the flange is dispensed with and the ring containing the teeth is bored to be forced on the cast-iron center and afterwards pinned to keep it from moving. The use of a bronze worm with either

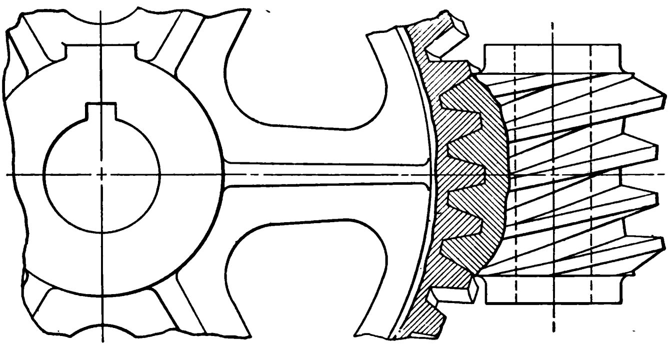


Fig. 50. Details of Hindley Worm Gear
Courtesy of Albro-Clem Elevator Company, Philadelphia, Pennsylvania

a cast-iron or a bronze gear was tried, but it was found that the worm wore out very quickly.

Gear-Tooth Construction. *Tooth Shape.* Various forms of teeth were tried out, but none of them seemed to produce any noticeable change. The tooth of the worm gear having a concave face cannot, of necessity, be straight across the face, the tooth tapering from the root to the point, and at the same time being thicker at the center of the face than at the outer ends. A tooth when viewed from the top is thus seen to have convex sides, the convexity being more pronounced at the point than at the root of the tooth.

Method of Forming. This shape is very difficult to produce in the gear cutter, in fact, only an approach to the proper shape can be made in this way. The best gears are first cut in a gear cutter and then finished with the hob. In cutting the teeth in the gear cutter three operations are necessary. First, the cutter is run in at the proper inclination with the face to produce a tooth at the angle required by the pitch and diameter of the worm. The result is a parallel tooth. Then the gear is skewed around to the proper angle and the cutter is run in again so as to taper the tooth at one end. The gear is skewed back to the same angle the opposite way and the cutter again run in, producing a tooth tapered at the ends but having by no means a true concave face. To make this curve the hob is used.

Details of Hob. The hob is a worm cut in the lathe in exactly the same manner as the worm that is to be used in the gear to be hobbed. It is made of tool steel suitable for the purpose for which it is to be used; and, after being turned, cut, and polished, it is fluted similar to the way a tap for threading nuts is made, except that its sides are parallel. In fact, it is really a large tap, parallel in the body and with a stem at each end. The stem is made as short as practicable for the sake of rigidity. After being tempered, it is mounted between the lathe centers and driven from the face plate by a suitable driver or dog. The gear to be hobbed is mounted on a table bolted to the saddle of the lathe, and is made to revolve horizontally on a pin on the table, being fed by hand up to the hob by means of the crossfeed of the lathe saddle.

Hobs are sometimes made of cast iron with steel blades inserted to do the cutting, but, although cheaper to produce, they are neither so effective nor so lasting. Some shops have a special machine to do the hobbing, in which the table to which the gear is attached revolves with the gear and is driven by gearing connected with the hob, so that both run in unison. With this arrangement, gears can be cut from the solid material with the hob, and consequently a much better and more perfect gear can be made.

Operating Characteristics. *Pressure Distribution.* To understand the necessity for this shape of tooth and the distribution of pressure, refer to Fig. 43. The worm, it must be remembered, is cylindrical in shape with a helical tooth wrapped around it. In its relation to the gear the worm is tangent to its periphery. Now, during a revolution of the gear, the first points of contact with the worm are made at the extreme outer corners of a gear tooth, and it will be readily seen that the tooth must be thinner at this place because otherwise it would not enter the worm. For this very reason, and also because of the concavity of the face of the gear the worm at this position of the tooth bears only at the two outer corners of the tooth. As the gear revolves, however, the points of contact gradually change toward the center of the face of the tooth until the gear tooth is fully in mesh with the worm, as shown by the tooth on the center line in the figure. At such a time the pressure is only at the center of the face of the tooth and, as the gear tooth passes this place and moves on until it leaves the worm, the point of contact is divided and gradually spreads until it is at the same two outer corners again when the tooth leaves the worm. It will thus be seen that the worm does not bear over the entire surface of the gear tooth at any time, but that the surface in actual contact is always quite small in area. Of course, the fact that several teeth of the gear are partly engaged at one time helps to distribute the pressure, but this distribution depends upon the accuracy with which the gear is made.

Motion at Contact Points. In a spur or bevel gear the motion of the teeth on the surfaces in contact closely resembles that of two rollers running together, but in the worm and gear it is very different. It is a compound motion made up of a sliding motion produced by the revolutions of the worm across the face of the gear, and a circular motion brought about by the spiral advance of the thread of the worm. The threads of the worm advance in a straight line parallel with the center of the worm shaft, so that the advance of the worm threads may be compared to the movement of a rack driving a spur gear. This complexity of motion between the small areas of contact, and their constant changing of position, not only make the pressure per square inch very great, but are conducive to friction and cutting.

Lubrication. On account of the friction the lubricant used should possess the power of resistance against being forced out from between the surfaces. Animal oils possess this quality in a more marked degree than either vegetable or mineral oils, the latter being the least valuable for the purpose. A good quality of lard or neat's-foot oil is the best that can be used if the service required is severe, and a small quantity of the best quality of lubricating plumbago will increase the staying qualities of the oil. The plumbago will coat the surfaces of the teeth and threads and, as no amount of pressure will remove it, it really lubricates. Beef or mutton tallow melted and stirred into the oil before introducing it into the housing containing the worm and gear gives the lubricant greater body or power of resisting pressure. The proportions found to be best for tallow are from two to three pounds of tallow to a gallon of oil, and for plumbago, about a handful of plumbago for the entire quantity of oil used at one time. This quantity of oil varies with the size of the housing, for enough oil to nearly immerse the worm should always be in the housing.

Another good substance to use in oil for the purpose of giving it a body is white lead. It has the quality of resisting heavy pressure and will not cause trouble by drying after being mixed with the lard, or with sperm or neat's-foot oil.

Castor oil is, on account of its viscous qualities, very good, provided the service required is not too severe, but it has the objectionable feature of disintegrating when heated. When the service required of the worm and gear is such that it heats under heavy and continuous work, this oil first becomes thin and then separates into a watery fluid having no lubricating qualities and a thick, ropy, glutinous semi-solid, like India rubber in appearance, which sticks to the sides of the housing. An oil which fails like this at the very time a good lubricator is most needed is not to be recommended.

To resist heating nothing is better than flour of sulphur. This mineral is suggested because, having been sublimated, it is likely to be free from earthy impurities, and because it is in a state of fine division, a condition which is favorable to its working into the places where most needed.

End-Thrust Blocks. *Button Type.* About the year 1873, having met with considerable trouble on account of the heating and sticking of the thrust bearings at the ends of the worm shafts, the writer devised the form of end-thrust buttons referred to on page 46; this form proved very effective and serviceable, and is a favorite with most elevator builders today. This end-thrust device is very simple in construction, comprising merely several disks of metal, being alternately of tempered steel and hard, tough bronze, as shown in Fig. 51. They are made slightly smaller in diameter than the worm shaft, partly to allow free circulation of oil around them, but principally to produce an eccentric motion in order to keep the surfaces in contact constantly changing, and thereby lessening the liability to stick to one another. To further facilitate the flow of oil between the bearing surfaces, an oil groove should be cut clear across the face of each disk, being careful not to have the grooves on the opposite sides parallel to each other, but rather at right angles. This precaution is taken to avoid weakening the disks, which should be from $\frac{3}{8}$ to $\frac{1}{2}$ inch thick when new, and which must be renewed after they have worn down to $\frac{1}{4}$ inch in thickness. Under ordinary conditions, this does not take place for a year or two—in fact, they have often been known to last for a period of four years before requiring renewal. The bronze disks always wear out more quickly than the steel. Should the thrust buttons, as these are called, require attention either from heating or cutting, or from

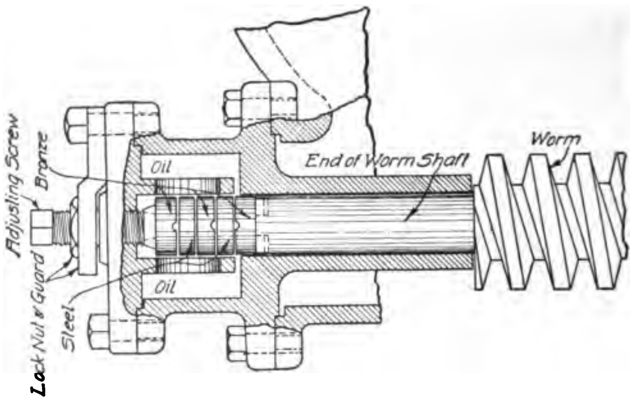


Fig. 51. Diagram of Worm Thrust Block, Showing End-Thrust Buttons

wear, they are readily accessible by taking out the back head. But it must never be forgotten that several precautions must be taken before doing this. The cage should be blocked, and the hoist cables should be made slack enough to remove the strain on them by backing the machine a little after the cage is blocked, while the oil should be drawn from the reservoir.

Collar Type. When the counterpoise weight in use is heavier than the cage, provision has to be made for thrust in the opposite direction when the elevator is running with no load. Then the counterpoise weight pulls the worm toward the front head of the shell. To meet this condition, rings of brass and steel are used, being slipped over the worm shaft and placed between the end of the worm and the end of the front head of the shell as shown in Fig. 52. The work required here being neither so constant nor so severe as with the thrust buttons, one bronze ring is frequently found to be sufficient. It can be from $\frac{1}{2}$ to $\frac{5}{8}$ inch in thickness, and should be bored fully $\frac{1}{32}$ inch larger than the worm shaft in order to produce the eccentric motion while revolving, which tends to prevent the wearing of grooves in the wearing surfaces. For the same reason the outside diameter of the rings should not be larger than that of the end of the worm and front head, otherwise a shoulder will be worn in the ring which will in time defeat this object. The end of the front head must be protected from wear by facing it with a steel ring pinned on the end of the head, cast iron being a poor material for withstanding this kind of wear under presssure. In all cases where the amount of over-counterpoise is great, it is best to use three loose rings, the middle one being of steel, about $\frac{3}{8}$ or $\frac{5}{16}$ of an inch thick, and the two bronze ones $\frac{1}{2}$ inch in thickness. The steel rings at this end need not be hardened, the

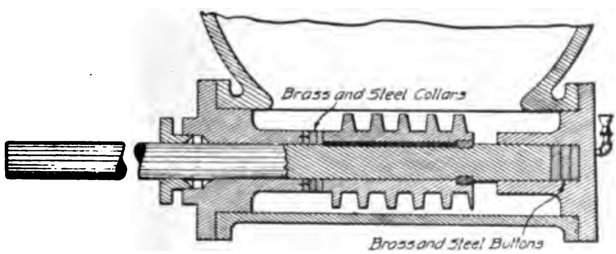


Fig. 52. Worm Thrust Block, Showing Use of Buttons and Collars

work to be done at this point being intermittent and never so severe as with the thrust buttons at the end of the worm shaft. The changing of the thrust from one end of the worm to the other, brought about by variations from no load to full load, introduces another condition which has to be taken care of, and which does not exist where the counterpoise is lighter than the cage. This is lost motion caused by wear. In the case of a counterpoise lighter than the cage, the pull is always in one direction, and any wear of the thrust is taken up automatically; but, in the case of the heavier weight, whenever a load is removed from the cage, the excess amount of counterpoise weight pulls the worm up against the rings and *vice versa*. When the load on the cage is in excess of the extra amount of counterpoise weight, it pulls the other way.

This matter of counterpoise may seem insignificant to the reader, but in reality it is very surprising in its effects, for, the drum being always larger in diameter than the gear, the lost motion is somewhat magnified at the floor of the car and gives rise to the impression that something is loose and liable to give way. Moreover, the change of position of the worm is accompanied by a loud noise resembling a blow with a heavy hammer, the sound being produced inside the shell or gear casing. This is more noticeable when a load which about balances the amount of extra counterpoise is on the cage. In this case, when the brake is applied to stop the elevator, the noise is very pronounced. To remedy this trouble a set screw and lock nut are used in the back

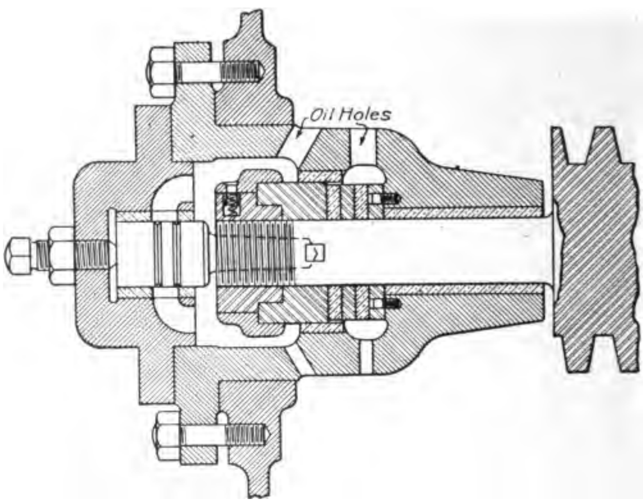


Fig. 53. Taper-Plug Type of End-Thrust Block

head to move the back block forward, when required to take up wear. In adjusting this block, care must be taken not to set it up too tight or cutting will result. A small amount of play, about $\frac{1}{64}$ of an inch, is desirable and absolutely necessary to allow the lubricant to flow between the surfaces; but when the wear amounts to $\frac{1}{16}$ of an inch the noise becomes very loud. Under proper conditions, however, it requires many months to wear to this extent.

Steel-Plug Type. Several other forms of thrust device have been devised, some of which will be described here. One method was to bore the end of the worm shaft in a tapering manner similar to the nose end of a lathe spindle and fit it with a tapered steel plug, the end of which was enlarged to the diameter of the worm shaft, Fig. 53. This steel toe, as it is called, was tempered and made to run against a tempered thrust block somewhat similar to the toe and step used in the spindles of the old burr-stone mills used for grinding wheat, and which doubtless inspired the idea for this form of thrust.

Loose-Ring Type. Another method was to use loose rings at both ends of the worm instead of at one end of the shaft. These, however, did not give the amount of wear expected of them and caused some trouble on account of heating. However, they are still in favor with many makers.

Ball-Bearing Type. The thrust block which seemed to give the greatest promise of good results was the ball-bearing, and, although it did prove very satisfactory at first, it was found that under light loads it was not durable, and that under heavy duty it failed entirely. The balls were of steel, one-half inch in diameter, and were usually inserted in a perforated plate about $\frac{5}{16}$ or $\frac{3}{8}$ of an inch thick. Holes were drilled in the plate, so that the balls did not run in the same circle, and a steel plate was placed on either side to take the pressure, the whole being located in a separate chamber kept supplied with oil. Under heavy pressure the balls would crush, and under fairly favorable conditions they would cut grooves in the plates or would wear flat places on themselves. As a result of these defects this form of thrust is very little used today.

Worm and Gear Proportions. The best proportions for a worm and gear for elevator service are as follows, based on the actual experience of some of the more prominent makers of elevators:

The diameter of worm should not exceed one-fifth the diameter of the gear, and the face of the gear should be about two-fifths the diameter of worm. These proportions are not arbitrary, but are approximately what have been found to give the best results.

The pitch of gears and worms for loads from 1500 to 2500 pounds should be about $1\frac{1}{4}$ inch; from 3000 to 5000 pounds, $1\frac{1}{2}$ inch, and from 5000 to 7000 pounds, $1\frac{3}{4}$ inch. The number of teeth in the gear does not differ widely, 45 to 50 teeth in the gear being sufficient for light capacities, and 50 to 54 teeth being suitable for high capacities. In fact, 50 teeth for any of them will give good results. The proper widths of belts and speed of pulleys will be considered under the head of horsepower.

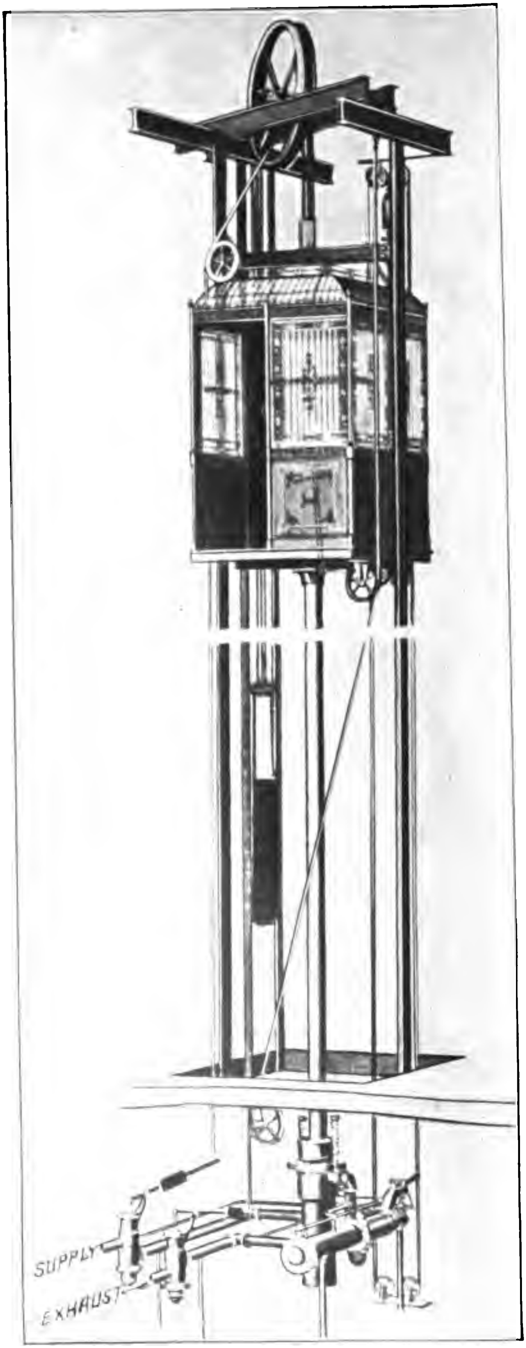
The Tandem Worm and Gear. Before leaving this subject, it is well to mention another form, or rather, combination, of worm and gear which has been in use for very many years and is today advocated by some makers of elevators, namely, the tandem worm and gear.

It comprises two worms on one shaft, situated far enough apart to allow the respective gears to clear each other. (See Elevators, Part III, Fig. 153.) The worms as will be seen in the diagram are of the sames pitch, but one is a right- and the other a left-hand thread, the gears being built accordingly. At the side of each worm gear a spur gear of suitable diameter to mesh with the other is placed. In ordinary use only one drum is used. This is connected to one of the gears, the other running as an idler, its office being to distribute the pressure.

The advantages derived from this form of gearing are, first, the elimination of the thrust bearing, the thrust being taken up between the two worms and equally divided between them; and, second, the reduction of the actual pressure between the tooth of the gear and the thread of the worm. In cases where the work to be done or the loads to be lifted are excessive, this arrangement has its advantages. In some cases it has been used as a duplex machine; that is, two sets of tandem gearing have been run side by side, each worm shaft being driven separately by its own motor, but with the motors coupled or connected to the same controller so as to be actuated in unison. To further insure uniformity of action, the worm gears were connected by spur gears meshing together. If this precaution were not taken, a slight movement of one worm shaft in advance of the other would have the effect of locking the machine; but arranged as described, the gearing works harmoniously, and the load or pressure on the teeth of gear and the threads of worms is divided by four.

The disadvantages are cumbersomeness and expense, for every part in it so far as relates to the worm and gear is duplicated. Additional parts are required, such as the spur gears, etc.

When first introduced, more than thirty years ago, spur gears were not used, but the worm gears were made as spur gears, with their teeth set diagonally to suit the angle of the worms, and these gears meshed into each other. This form of gear did not give satisfaction in point of durability and was abandoned for the present arrangement.



DIAGRAMMATIC VIEW OF PLUNGER HYDRAULIC ELEVATOR

Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

ELEVATORS

PART II

STEAM ELEVATORS

HISTORICAL DEVELOPMENT

Economy in Power No Desideratum. The first direct application of steam to the operation of elevators, which occurred in the sixties, seems to have been, as far as economy of power was concerned, as successful as any subsequent effort. Later, more compact machines were devised, but all of them with one exception were very inefficient. In those days economy in power in the case of the elevator was not a desideratum; lifting power and speed were the objective points, and they were certainly obtained.

Up to the year 1858, the only elevators propelled by power were the worm-gear or spur-gear type. They were driven at a very slow speed by two belts from a line or countershaft and were used only for carrying freight. In that year the first passenger elevator was installed in the Astor House in New York City. It was one of the two-belted worm-gear type, and its speed was only 50 feet per minute.

Retention of Gear Transmission. It was only natural that, in applying steam direct, the worm and gear and the spur gearing should have been retained as part of the apparatus, just as it was nearly forty years later in the first effort to apply electricity to the same purpose.

Worm-Gear Type. At first a reversible, link-type, vertical two-cylinder engine with a 3-foot pulley on the crankshaft, as shown in Fig. 54, was used. The worm-gear winding apparatus was mounted on the floor of the engine room and provided with a 16-inch pulley for belting it to the engine, which was mounted on a separate foundation a few feet away. There was no need of a belt-shipping device, for the link-motion reversing gear on the engine performed the duties of controlling the direction of the running of the engine, and hence of the elevator. In order to obtain the necessary stroke of the operating cable for controlling the car at a high

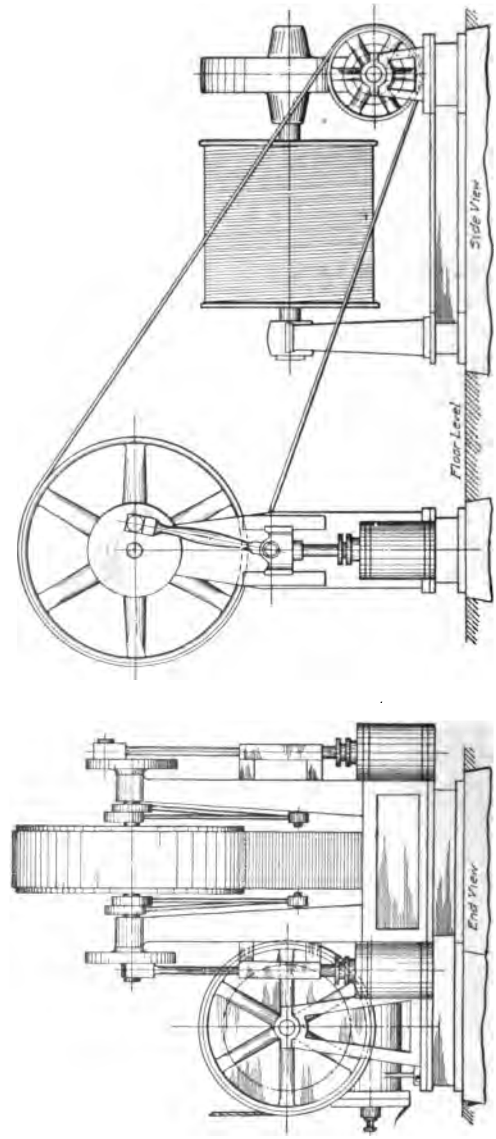


Fig. 54. First Steam Elevator. Belt-Driven from Engine; Worm-Driven Winding Drum

speed, a cut gear was attached to the rockshaft of the engine, this gear being operated by a pinion of suitable diameter. On the pinion shaft was keyed a sheave around which the operating cable was wound two or three times and fastened. This arrangement gave a stroke of from two to two and one-half feet to the cable in either direction—a decided necessity for slowing down and stopping when running at a high speed. No brake was used, as all the worms in use with elevators at that time, and for years after, were of the single-thread type, in which the thread angle did not exceed 10 to 12 degrees. Hence it was not likely that the load would ever start

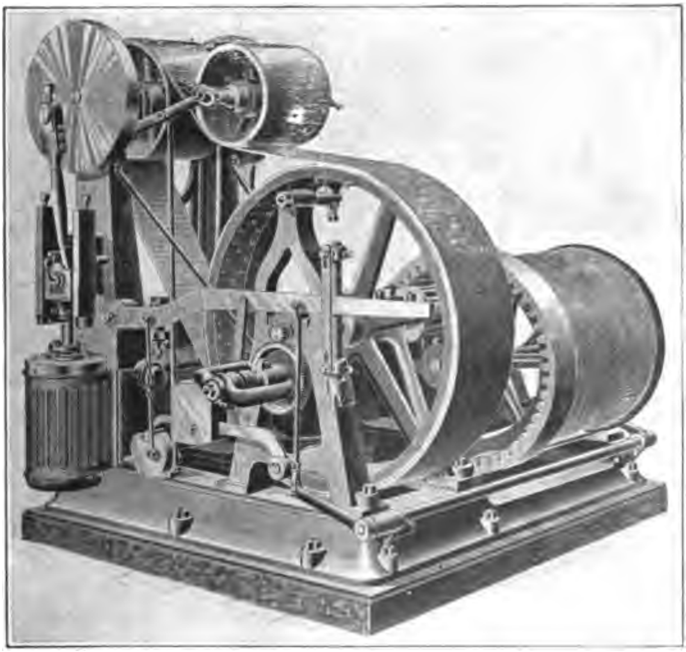


Fig. 55. Steam Elevator with Internal Spur-Gear-Driven Winding Drum

down from a state of rest, especially as it would have to drive the engine to do so.

This machine, while occupying considerable floor space, did not consume steam while the elevator was at rest and was very efficient, being a decided improvement over the old arrangement. But it was not long before efforts were made to design a more compact machine, and, while quite a number of contrivances resulted from these efforts, it is thought best to discuss only those which were successful and which stood the test of practical use.

Spur-Gear Machine. The spur gear was tried and, after many experiments, an engine with the steam apparatus, winding drum, and gearing all on the same bed, Fig. 55, was introduced and became popular. On the winding drum an internal spur gear and pinion was used, and the former order of pulley arrangement was reversed, the larger pulley being placed on the pinion shaft and the smaller one on the crankshaft of the engine. While the diameter of the latter was retained, that of the former was increased to four feet and necessarily fitted with a brake pulley attached to the arms inside the outer rim for, it will be remembered, a spur-gear machine is not self-locking. The pulleys were reversed and changed in size in order to reduce the driving ratio between the engine and the drum. This was necessary because the substitution of a spur gear for a worm gear increased the mechanical advantage between the pinion and the drum, owing to the fact that one revolution of a pinion causes a greater movement of a gear than one revolution of a worm used with a similar gear.

Another feature was necessarily introduced because, with the use of the spur gearing, it became unsafe to use the link motion as a reversing gear. Should the operator, when handling a heavy load, fail to throw the link motion completely, in the right position, the engine would not receive enough steam to handle the load and the car would back down against the steam; similarly, in lowering a heavy load, the car would run down too fast.

Automatic Steam Valve Developed. It was therefore necessary to devise a valve that would give the required amount of steam automatically and independently of the operator. Several types of valves were devised, the best and most successful of which will be here described.

Otis Tufts Valve. The Otis Tufts Company of Boston probably designed the first valve of this kind, Fig. 56, and it proved one of the best at that time. A sliding plate, *B*, was used between the distributing valves and the cylinder faces. This plate had two sets of ports with a blank space between, and it was arranged to slide at will at right angles with the axis of the cylinder. When placed in the central position, it completely closed the cylinder, preventing either ingress or egress, and in this way would stop the machine. When moved to one extreme of its travel, the ports were so arranged that the distributing valve would let steam in directly to either end of the cylinder exactly as in an ordinary steam engine, the middle port being the port of egress or exhaust. The engine would run, of course, in the direction for which the eccentric was set.

When, however, this plate was moved to the opposite end of its travel, it reversed this order, for the steam which was admitted by

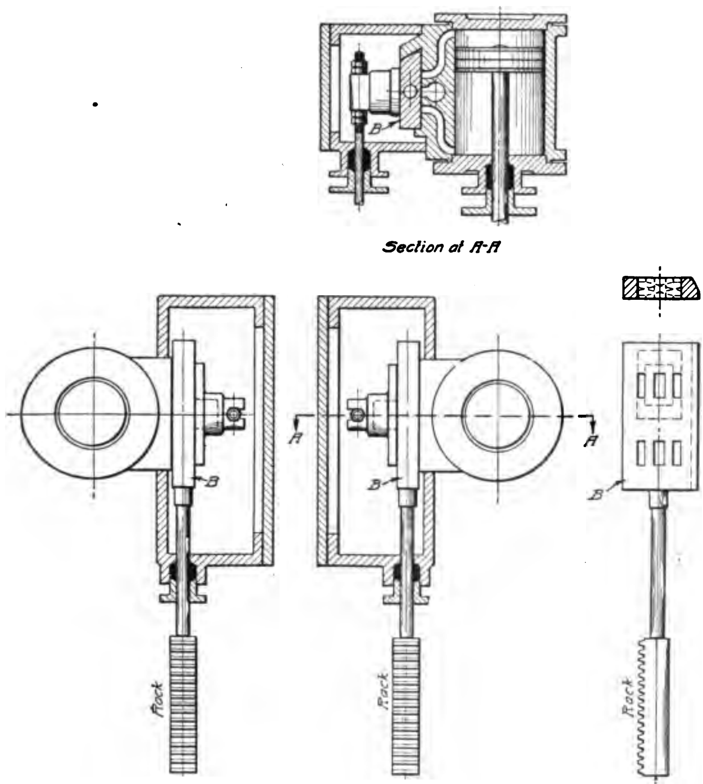


Fig. 56. Otis Tufts Automatic Steam Valve

the distributing valve to the upper port was carried down through the plate to the lower port of the cylinder and, after being admitted to the lower port in the plate, was conveyed to the upper port of the cylinder. By this means, a reverse motion was obtained without the use of the link motion and at the same time only one eccentric and rod were required. However, no lap or lead could be used on the distributing valve, the stroke being always the same. This arrangement was not economical of steam but it was effective and safe. As in the case of the link-motion engine, a double-cylinder machine, with the cranks set at right angles and a steam chest common to both cylinders, was used and no throttle valve, the sliding plates just described performing the office of throttle valve, when placed in the central position. Steam was always on in the steam chest and, to prevent the access of water of condensation to the cylinders, the bottom of the steam chest was made two or three inches lower than the bottom port of the cylinders and a pipe led from the lowest part of the steam chest to a steam trap. In this way the trap removed water from the steam chest as soon as formed.

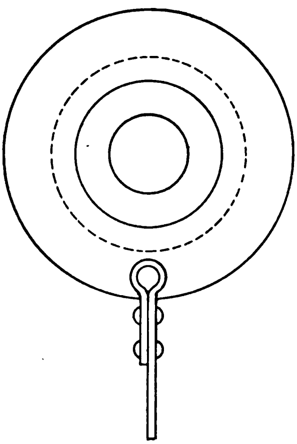


Fig. 57. Sheave for Steam Valve Mechanism

The movement of the plates in unison was effected by running valve stems from them out through stuffing boxes in the front of the steam chest. Each valve stem was fitted with a rack which meshed into a pinion on a rock-shaft. On the end of this shaft was fastened the sheave to which the operating cable was fastened and around which it passed. Hence a movement of the operating cable effected a movement of the plates and a corresponding performance of the engine. On this rockshaft was also keyed a sheave, a view of which is shown in Fig. 57. It was about 3 inches in diameter and had flanges on each side through which a pin was passed from side to side. It was keyed to the rockshaft in such a way that when the rockshaft was in the stop position the pin was at the top. To this pin was attached a leather strap which led up to and over two sheaves on the ceiling of the room where the engine was located. One of these sheaves was directly over the rockshaft and the other above the end of the brake lever, the strap being passed over these sheaves to the lever. If the rockshaft was revolved in either direction, it would wind up the strap and lift the lever, thus releasing the brake simultaneously with the turning on of steam to the engine. When the rockshaft was returned to the stop position and the strap unwound, the brake was applied by a heavy iron weight on the brake lever.

Miller Valve. The Miller valve motion, shown in Fig. 58, was another device designed on lines similar to that of the Otis Tufts. It had the plate between the distributing valve and the cylinder face, but it was made circular in shape. In effecting the change in direction of the engine movement the plate was caused to revolve

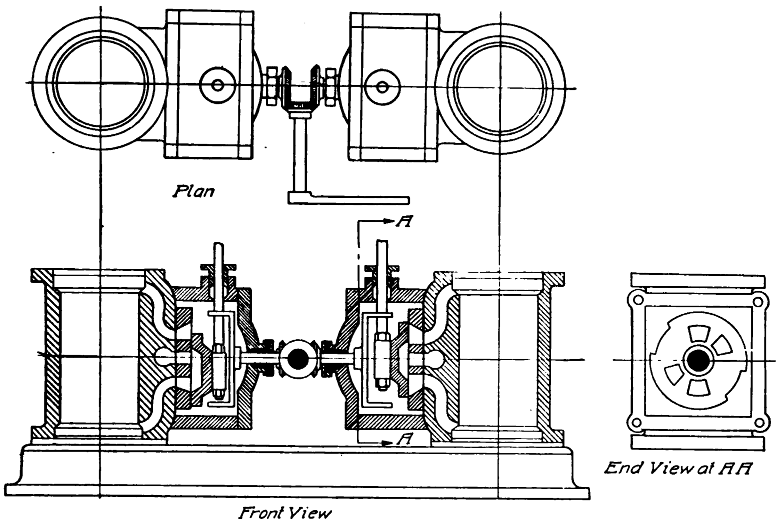


Fig. 58. Front Section, Plan, and End View of Miller Steam Valve

on a hollow gudgeon or pin cast on the cylinder face and acting as the exhaust port.

The brake in the Miller valve mechanism was released and applied exactly as in the case of the Otis Tufts movement. This valve gearing had many disadvantages, the principal one of which was the very contracted steam ports which its construction necessitated. Another was the necessity for two separate steam chests and an independent throttle valve which had to be operated from the rockshaft.

Otis Valve. The Otis Company of New York used two piston valves, as shown in Fig. 59. The piping or steam passages were cast in the back of the steam chest and met in the center of same, where a change valve was used to shut off the steam from the cylinders or change the direction of running as desired. Instead of causing the distributing valve to act as a throttle, when in its central position, as in the case of the Otis Tufts valve, or of using a separate throttle, as with the Miller valve, a third piston valve was introduced. This performed the double office of changing the direction of the steam as it entered the engine, and also that of shutting off the steam when desired. These valves were fitted with rings similar to a piston and were closely fitted. The ports through which they admitted steam were cast slightly diagonal to prevent the rings from catching in their edges. This feature also had the effect of causing the valve to cut the steam off very gradually instead of abruptly. Their construction was such that they were always balanced; in other words, they were subject to no pressure from the steam—a feature

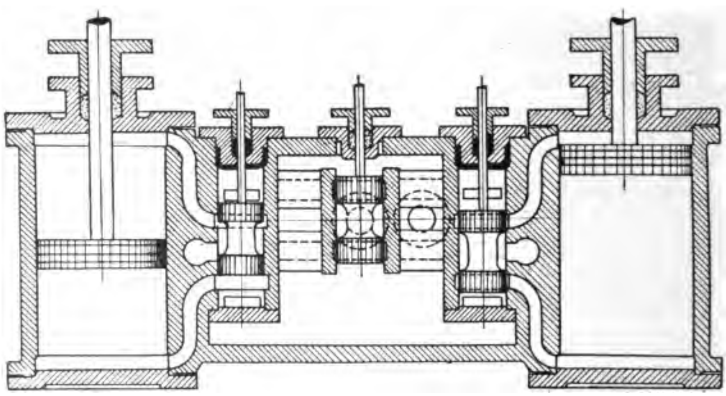


Fig. 59. Section of Otis Steam Valve

which both types of valve previously described did not possess. This elimination of the steam pressure from the back of the valve reduced friction, and, everything considered, the Otis valve was a decided improvement on the other two. Its chief defect was the difficulty experienced in keeping it tight, that is, in preventing the steam from leaking through it.

Crane Valve. In the latter part of the sixties another valve was introduced by the Crane Company of Chicago. This was really a simpler and a better valve than any of the preceding and it became quite popular throughout the West, although the Otis Company continued to make and use their valve until the steam elevator went out of use. The Crane valve comprised a change valve and two distributing valves similar in construction to that of the ordinary slide valve used with the common slide-valve steam engine, except that the distributing or cylinder valves were double.

Fig. 60, which shows a section of the valve and a portion of the cylinder face, gives a clear idea of its construction. *A* and *C* are the cylinder ports leading to each end of the cylinder. *B* and *D* were used either for exhaust or supply ports as required. The annular space at the back of the distributing valve was simply a passage for the service of port *A*. If the supply of steam came through port *D*, it passed through the passage at the back of the valve and was ready to pass into port *A* whenever the valve was moved far enough to open that port. On the other hand, if by moving the change valve the steam was admitted through port *B*, then port *D* became the exhaust port and the passage at the back of the valve would take the exhaust steam away from port *A* to *D*. Changing the direction of the steam in the manner described above would produce a reverse motion of the engine with an exactly similar motion of the distributing valve, so that but one eccentric and rod were required to produce and govern both motions. But with a reverse motion produced in this manner it would be impracticable to have either lap or lead with the valve, for the valve must be so made that it just covered the cylinder ports when central, as shown in the cut. This was the cause of a great deal of waste, but it could not be avoided, and in the case of a spur-gear engine it was necessary for safety.

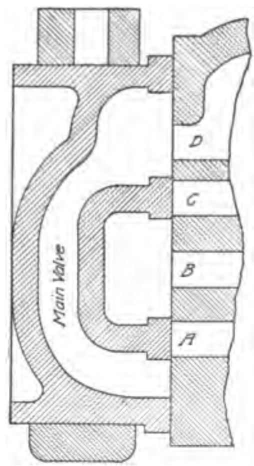


Fig. 60. Section of Crane Steam Valve

A casual inspection of these distributing valves will show that the area of the back of the valves exposed to the pressure of steam in the common steam chest provided is greater than the area of either of the ports in the valve, and only one of these ports is used at a time for line steam. Hence, because of the greater area of the back of the valves and, therefore, of the greater pressure, they are always held to their seats. However, if the elevator car should be very much overloaded, it is possible for the car to drive the engine if spur gearing is used. In such a case the engine would run backwards and pump air into the boiler. The pressure under the valves would become greater than that on the outside, and the valves would be forced off their seats. The car would run quickly to the ground and the valves remain off their seats, thus crippling the engine. To prevent such an occurrence, guides were bolted to the bottom of the steam chest in such a way that, while permitting the free travel of the valve, the latter was held tight against its seat. Such an arrangement was absolutely essential in an engine fitted with this type of valve motion if spur gearing was used. With worm gearing it was, of course, impossible for the car to drive the engine.

TYPE OF ENGINES

Vertical Cylinder. The engines used at this time were 7-inch bore of cylinder and 9-inch stroke, and the steam pressure was from 80 to 90 pounds per square inch at the boiler. The engine's speed was up to 200 to 225 revolutions per minute and, with the gearing and drum already described, the speed of the car with the worm gearing was about 100 feet per minute, while after the introduction of the internal spur gear a car speed of 200 feet was easily attainable. This was, at that time, the greatest speed which had been attained with elevators. It soon became apparent that higher speeds could be had if the means of stopping were adequate. This feature proved to be a very serious obstacle, and one which was not overcome until later, when the lever device for use with hydraulic elevators was evolved. Many operators developed marvelous skill in handling cars at what were considered high speeds, but these were exceptions.

All the engines in use at this time were similar, being of the vertical cylinder type. For greater loads an engine having cylinders of 8-inch bore and 10-inch stroke was used, while for light loads of one ton or less, a 6- by 8-inch engine was employed.

Direct Connected. In the seventies an engine which was directly connected to the worm shaft was built, Fig. 61. The same floor type of worm gear and housing was used, but it was bolted to an extended bed, the worm shaft being also extended. Where the worm shaft projected beyond the housing it was formed into a double crankshaft, the bed being provided with pillow blocks for it to run in. Above this the cylinders and steam chest were set on suitable frames, with sufficient space provided between the cylinders and crankshaft to allow room for the guides, crossheads, and a proper length of connecting rod, the valves and valve mechanism being either of the Crane or Otis type.

The initial machine, which was installed in a building on State Street, Chicago, was somewhat unsatisfactory at first, but eventually this type of machine became very successful. The principal modifications found essential to success were: double-thread worm and gear, larger diameter of winding drum, and heavy balance wheel on the crankshaft between the cranks. The heavier balance wheel produced a more steady motion in the engine, especially when running at low speeds, while the worm of greater pitch added to

Fig. 61. Direct-Connected Steam-Driven Elevator

the speed of the car, as did also the larger drum. The speed of the engine was also increased by making the steam passages of greater area. These engines were operated through the medium of a hand cable, because at that time it was the only known means.

Introduction of Pilot Valve. Later, when the pilot valve was introduced with the hydraulic elevator and the hand cable was displaced by the lever-operating device, it was seen that this medium of operation would be an improvement if applied to the steam elevator. But in order to make it available for use with this machine, a special form of change valve had to be devised. To supply this need a valve was made in the form of a hollow cylinder, which was turned to fit accurately in a valve casing previously bored true and smooth, and a ground fit.

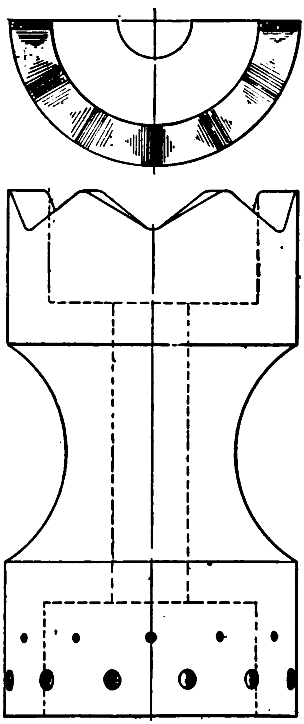


Fig. 62. Special Type of Steam Valve

The advantages of this form of valve were that very little power was required to move it because of the valve being balanced, and that the ports in the valve casing were of increased area as a result of the cylindrical form. The valve was 3 inches in diameter, so the port in the casing, which extended entirely around the valve, had a virtual length of more than 9 inches. The travel of valve, therefore, could be much less than in the flat type. In order to admit and cut off the steam gradually, that end of the valve which let in steam to the hoisting ports was made wavy, as shown in Fig. 62. For the lowering end, only a few holes were necessary, as it required but very little steam to run the engine at a fast speed while lowering. At the same time, the load was never able to drive the worm, turn the crankshaft, or move the pistons and rods without the aid of steam, hence no brake was required.

The introduction of this type of change valve, which was used only with the direct-connected worm-gear machine, permitted the application of the lever device to the steam elevator. With this improved method of control, much higher speeds were made practicable. Then another change was made, namely, the use of the three-thread worm and gear. This made it quite easy to reach car speeds of from 350 to 500 feet per minute with the larger engines and maintain complete control. Hence there was considerable competition between the makers of steam and hydraulic elevators.

The introduction of the electric elevator with its high speeds and its economical operation and maintenance gradually eliminated the steam elevator, and today there is hardly one to be found. But the fact remains that it was in its day a very efficient machine and more durable than the electric, the electric parts of which deteriorate rapidly.

HYDRAULIC ELEVATORS

EARLY FORMS

Armstrong Hydraulic Crane. The idea from which the hydraulic elevator was eventually evolved originated with Sir William Armstrong, an eminent English engineer. He was interested in a stone quarry situated in a hilly district in Yorkshire, England. About two hundred feet above this quarry was a reservoir of water used for the supply of a neighboring town. His idea was to use this water for lifting the stone out of the pit, and for this purpose he made the hydraulic crane shown in Figs. 63 and 64. It comprised a cylinder set almost horizontal—the cylinder being bored true and smooth and fitted with a piston rod—and a crosshead which ran on guides set in line with the cylinder. The crosshead was supplied with a shaft and sheave, grooved for the reception of a chain. The extreme end of the frame farthest away from the cylinder was equipped with two similar sheaves and shafts set one above the other, as shown.

One end of the chain used for lifting the loads was attached to the crosshead; after being led around the upper sheave of the frame and around the traveling sheave on the crosshead, it was carried under the lower fixed sheave, and from there up through the port of the crane and out to the end of the jib and down, terminating in a hook for hitching on to the loads, and having attached to it a heavy weight to cause it to overhaul when descending unloaded. To

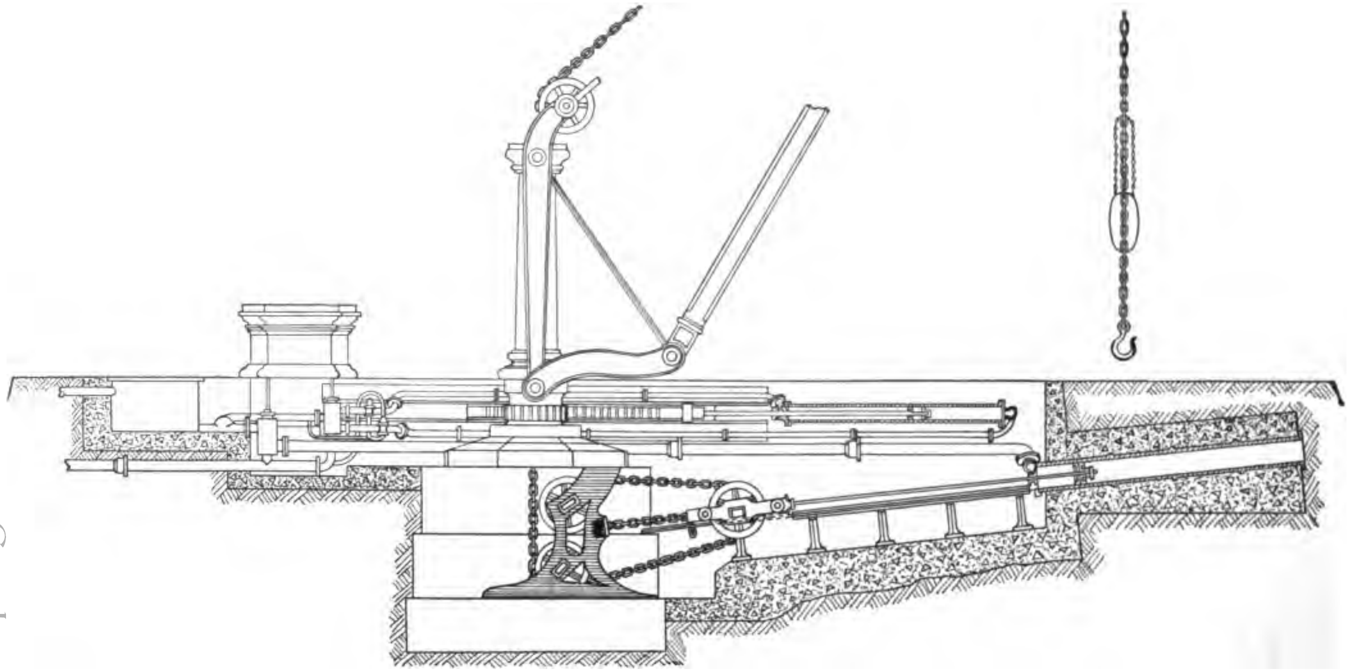


Fig. 63. Section of Armstrong Hydraulic Crane

facilitate this overhauling of the chain, the cylinder, instead of being set horizontal, was set at a considerable angle, all of which is clearly shown in the illustrations.

This machine was also equipped with an auxiliary cylinder, the piston rod of which was fitted with a rack meshing with a pinion

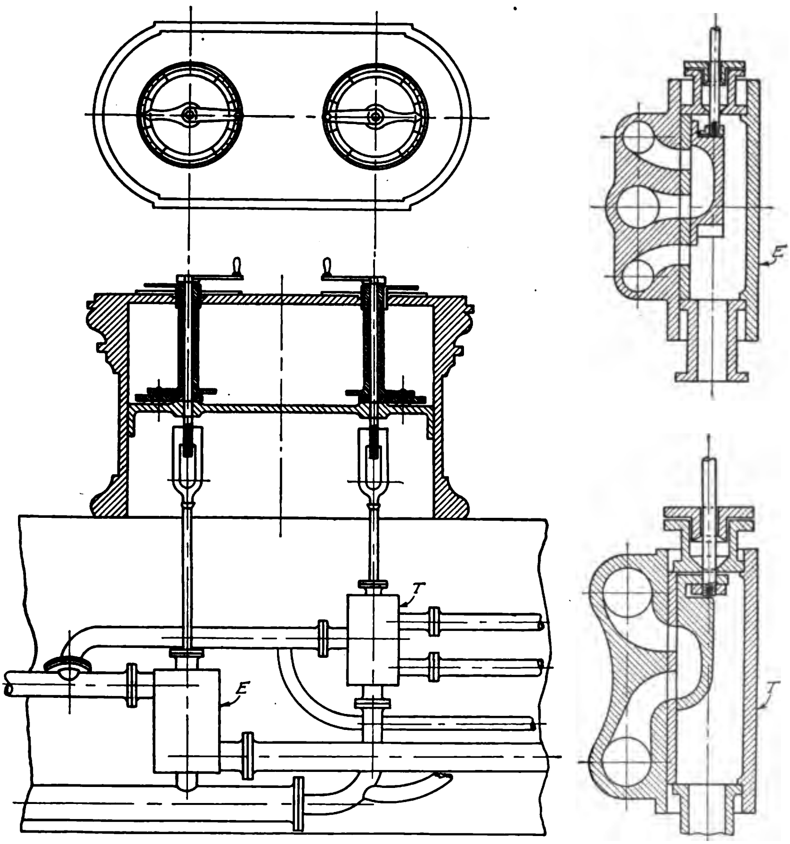


Fig. 64. Details of Armstrong Operating Valve

extending around the lower part of the crane port. This auxiliary cylinder was used for the purpose of swinging the crane around in a circle for convenience in depositing the loads at the top of the bank as well as for hitching on to them below. As this rack and piston necessarily had to operate in both directions, this cylinder had to take water at either end as might be desired, while the cylinder which performed the hoisting took water at one end only, the other being open to the atmosphere.

Adapted for Lifting Merchandise. This machine was so successful for the purpose for which it was designed that a few years later it occurred to the originator that it might be used for lifting merchandise in warehouses. As a result, many such machines were made and installed in England. In some cases, in order to save room, the cylinders were set vertical. These elevators were never supplied with a car or platform traveling in guides, but always with a chain and hook. That they were not an unqualified success may be readily seen by examining the details of the operating valve shown in Fig. 64. This was of the ordinary D-type, being similar to that used as the distributing valve on an ordinary slide-valve steam engine.

AMERICAN IMPROVEMENTS

It was about the year 1866 or 1868 that the Armstrong machine was introduced into the United States and, following the course of many other devices brought here from the Old World, it was wonderfully improved upon.

Addition of Platform. The first improvement made by the American engineers was the introduction of the platform or cage traveling in guides, which seemed to them so essential to a handy and convenient elevator. The horizontal type only was used at that time, and only where water under pressure was available or could be produced by pumping water to a tank on the roof. As buildings at that time seldom exceeded four to six stories in height, the pressure obtained in the latter case was never very great.

Use of Pressure Tank. Where a natural or artificial head was not obtainable, American engineers introduced a form of accumulator by using a pressure tank, the water of which was replenished by means of a pump. The pressure was produced by the use of air pumped into the tank under pressure, about one-third of the volume of the tank being occupied by air when the tank contained the maximum quantity of water used. The elasticity of the air permitted the elevator to make several trips before it became necessary to operate the pumps again. Where either a roof or pressure tank was employed, the same water was used over again, being discharged into a tank below the surface of the ground and then pumped back into the roof tank for use again; but where water was obtained from the street mains, it was discharged into the sewer.

Two-Way Operating Valve. *Early Forms of Operating Valve.* Another improvement made in the construction of the machine was the operating valve. Besides being difficult to keep tight, the old Armstrong valve, through having the pressure all on one side,

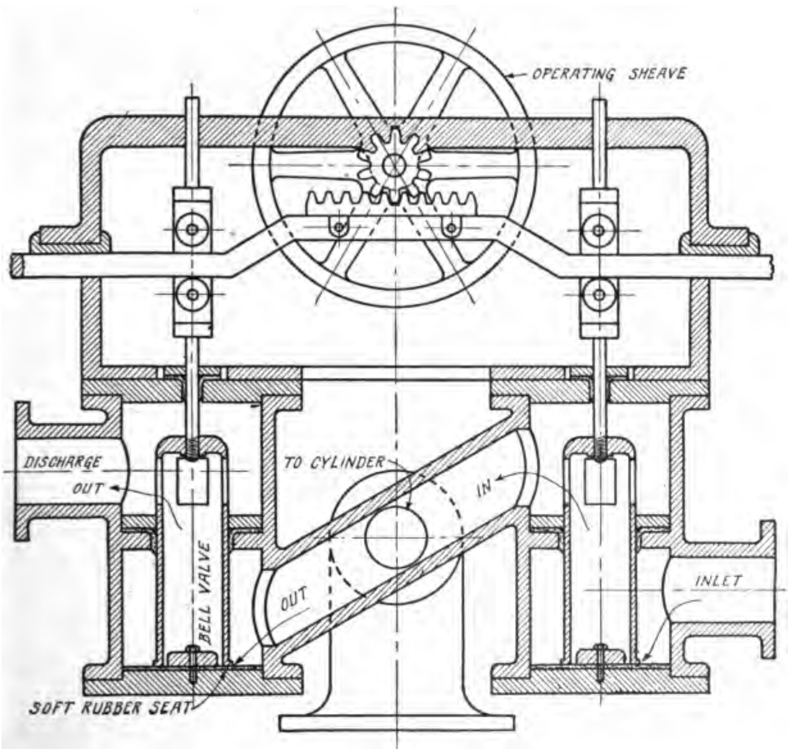


Fig. 65. Bell-Type Two-Way Operating Valve

required a great amount of power to move it. This feature made it unsuited for operation from a moving platform, so recourse was had to a design which was more nearly balanced, that is, one in which the pressure was not all confined to one side of the valve. Many types of valve were introduced, such as double poppet valves, and the so-called bell-type and bottle-type valves, Figs. 65 and 66. As all, or nearly all, of them fell into disuse and became obsolete,

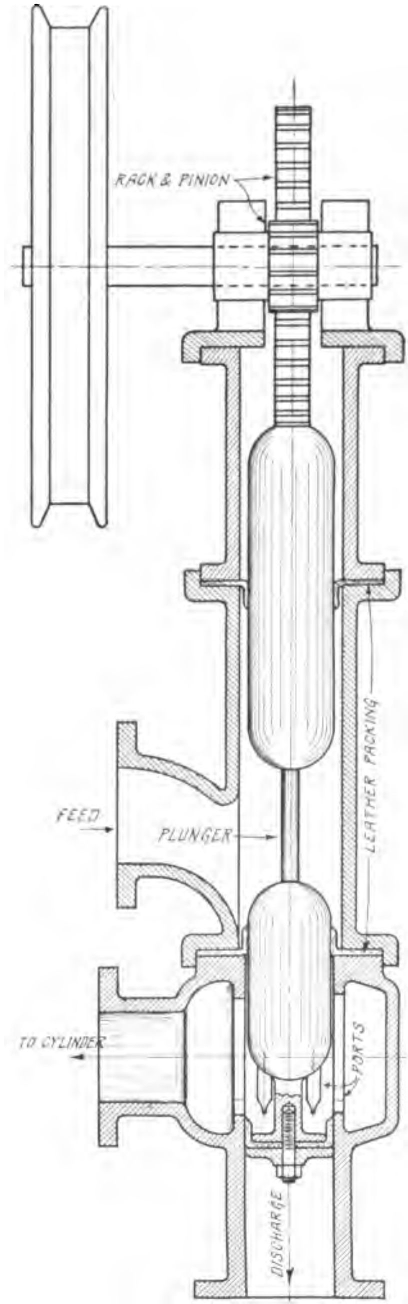


Fig. 66. Bottle-Type Two-Way Valve

only that one which most nearly filled the requirements, and which came into general use, will be described.

General Description of Two-Way Valve. The body of the two-way valve proper, which comprises the two middle sections *h h* shown in Fig. 67, consists of two short cast-iron tubes with flanges for bolting them together. These tubes are accurately bored and the flanges faced, and each section is lined with a piece of seamless drawn-brass tube one-eighth of an inch thick. This tube is as true and smooth as if turned and bored in the lathe, and is made a tight fit in the cast-iron casing, being forced into place under pressure. The lining *b* in the upper section is plain and does not extend the full length of the cast-iron body. It will be noticed that each section of this cast-iron body is somewhat enlarged where the nozzle or port enters. This enlargement permits of forming a passage for the water all around the brass lining to provide a full flow of water with as little hindrance as possible.

Brass Lining. The brass lining in the lower section extends from one-half inch above the upper flange of this section clear through to the lower flange. At the part which comes opposite to the lower port or branch marked "To Cylinder", Fig. 67, the tube is perforated by numerous holes of various sizes set evenly in rows. The combined area of all these holes must be one-third greater than the area of the internal section of the brass tube. The upper and lower rows of holes must be smaller than those toward the middle and not so numerous, the object of this being to admit and retard the flow of the water gradually. The extreme end rows of holes are usually $\frac{3}{16}$ to $\frac{1}{4}$ inch in diameter and those toward the middle increase in size, row by row, until they attain a diameter of from $\frac{7}{16}$ to $\frac{1}{2}$ inch. The laying-out and drilling of these holes is an important feature in the making of a valve, for upon it depends the smooth and gentle starting and stopping of the elevator. The operation of making these holes is called the "graduating" of the valve. The size of the holes, their distance apart, and their number vary with the size of valve used and the pressure under which it is to work.

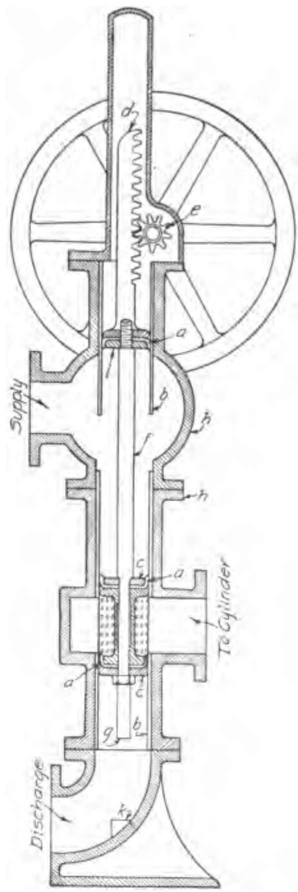


Fig. 67. Improved Type Two-Way Operating Valve

The upper end of this section of the valve lining is allowed to project one-half inch beyond the upper flange, in order that when the valve is assembled it may enter the lower portion of the upper section and thereby keep the two sections in line and true. To prevent leakage of water a "gasket" of paper, cut the size and shape of the flanges and dipped in boiled linseed oil, is slipped between them, and this is all the packing required for this joint.

On the top end of the upper section is bolted a hood, which forms a cover or protection for the upper end of the plunger and contains two boxes or bearings in which the pinion shaft *e* may revolve. At the bottom end of the lower section is bolted a casting which serves the double purpose of forming a base for the valve to set upon and also an elbow and discharge port for the valve.

Plunger and Packing. The plunger *f*, of this valve comprises a stiff steel rod or shaft, which is turned smaller at its upper end and threaded. Over this is slipped a brass washer or flange *l*, the office of which is to fill out and support the leather cup *a*, which is used as a part of the packing of the plunger. After this leather cup is put in place, the rack *d* is attached. This rack, which is previously put in the lathe and turned true at its lower end and along its whole length directly back of the teeth, is then drilled for a distance of one and one-half inches and tapped out to fit or screw on the end of the valve stem, thus holding the leather cup firmly in position. The other end of the valve stem is similarly treated. It is turned down smaller, but for a greater distance, to receive another brass casting called the spool and two brass cups or graduators. These castings form holders for leather cups, which are the packing at this part of the valve, and when in place are held there firmly by a brass nut and locknut. The end of the valve stem below these nuts is turned down smaller for a certain distance as at *g*, Fig. 67, and serves as a stop by striking on the projection *k*, thus preventing the plunger traveling too far in that direction. Its travel upward is stopped by the lower portion of the rack striking the hood.

Operation. The action of the valve is as follows: The position of the plunger, as shown in Fig. 67, is the neutral or stop position, that is, no water can get in or out of the cylinder while the plunger remains as shown. A movement of the wheel will cause the plunger to rise or fall according to the direction in which the wheel is turned, this being accomplished through the medium of the rack and pinion, the wheel being keyed to the pinion shaft.

Should the plunger be depressed, a clear path will at once be made for water to pass from the supply opening to the cylinder. Upon returning the plunger to its present position all motion ceases and the elevator comes to rest. If the plunger is raised, a clear passage is provided for the escape of water from the cylinder to the discharge opening. Permitting water to enter the cylinder from the supply source causes the elevator to rise, while allowing it to escape produces the opposite movement of the car or cage.

There are two features of this valve which it would be well to explain before leaving the subject, namely, the function of the upper cup and the principle and operation of the leather cups.

Function of Upper Cup. The upper cup is what produces the balance of the plunger. If the hood were water-tight and there were no upper leather cup, the water upon entering the valve through the supply would immediately force the plunger down to its lowest point of travel. It would then require considerable power to raise it to its neutral position. If the water pressure was 100 pounds per square inch and the valve of the 4-inch type, thereby giving a pipe area of 12.56 square inches, the pressure on the plunger holding it down to the lower end of the tube would be slightly over 1250 pounds. But by using an upper leather cup, and by screwing into a hole tapped in the lower part of the hood a discharge pipe for carrying off any leakage water, an opening above the upper leather cup to the atmosphere is provided. When the supply water enters the valve, it presses upward against the leather cup with as much force as it does downward against the lower portion of the plunger, thus balancing the pressures on the two sides of the plunger, the only resistance to its movement through the tube being the friction between the sides of the tube and the plunger.

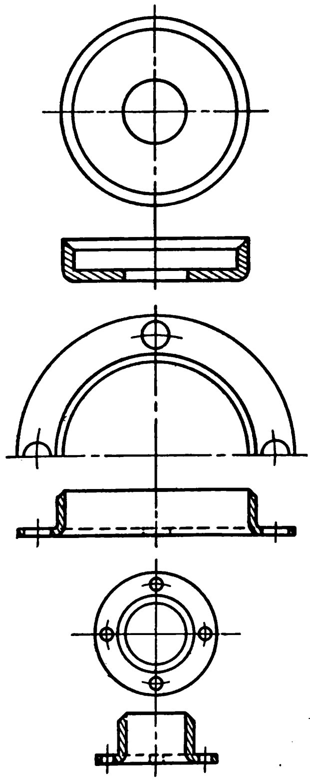


Fig. 68. Details of Leather Cup Construction

Construction of Cups. The leather cup is a very simple and efficient form of packing. The principle on which it works was discovered nearly a century ago by Joseph Bramah, who had experienced great difficulty in packing the ram of his hydraulic press. He finally overcame the trouble by means of a number of leather collars made as shown in Fig. 68. The leather cup used in the hydraulic valve is of the same type, but inverted, and is as nearly free from friction as anything of the kind can be made.

Belt leather $\frac{3}{16}$ of an inch wide makes the best cups because it is softer and more pliable than sole leather. After being soaked in water until soft and pliable, it is forced into a mold consisting of a collar, the base of which is of the same diameter as the outside of the cup is to be, and a smooth and true plug of the same diameter as the inside of the cup is to be. The inner edge of base of collar and the outer edge of plug are rounded so as not to damage the leather and to give the cup its proper shape. After the leather is laid on the collar in such a way as to have the hair side of the leather form the outside of the cup when made, the plug is slowly forced fully into the collar. The leather is then kept in the mold until dry, after which it is roughly trimmed by hand and put into a chuck in a wood-turning lathe and properly and truly turned, the "featheredge" being formed in this operation.

When the cup is made and put in place, it is, while in use, constantly immersed in water and would become soft and pliable again and rapidly assume its former flat shape, if not properly supported and protected. Hence the spool and other parts which hold the cups while in place in the plunger of the valve are shaped in such a manner as to retain the cup in proper form while in use.

It will be readily seen from this description and the accompanying illustrations that this packing is in a measure automatic in its action, for the pressure of the water on the inside of the cup is the cause of its holding the water. For this reason the holes in the brass lining must not be too large or the leather will be forced through them. Many makers have resorted to the expedient of milling a series of longitudinal slots in the lining instead of drilling round holes as described, but there seems to be no particular advantage in this and special machinery is required to make them. The leather cup is an important factor in the successful and efficient valve, and will be found in a more or less modified form in all that will be described hereafter.

DEVELOPMENT OF LATER LOW-PRESSURE TYPES

Early New England Type. About the time the horizontal hydraulic elevator of the Armstrong type came into use in the United States, another and similar machine of great simplicity was developed in New England.

In the State of Maine at that time, many of the stores and warehouses in cities and towns were low buildings of not more than three or four stories but of large area. Instead of using cylinders of comparatively large bore and a number of multiplying sheaves, long cylinders of smaller bore were substituted, with no multiplying sheaves. These cylinders were of the same internal diameter and made in sections of 10 or 12 feet in length bolted together to form one long cylinder, the length of which was equal to the travel of the cage. They were carefully lined up on piers of masonry set in the ground beneath the first or ground floor, as shown in Fig. 69. The piston was about three or four feet in length, and about four $\frac{5}{16}$-inch or $\frac{3}{8}$-inch steel rods were used in place of the regular piston rods. These rods passed through separate stuffing boxes in the cylinder head and under a sheave of large diameter, grooved to receive them, and thence up the hatchway to a similar sheave at the top of the run, and over this sheave down to the cage as shown.

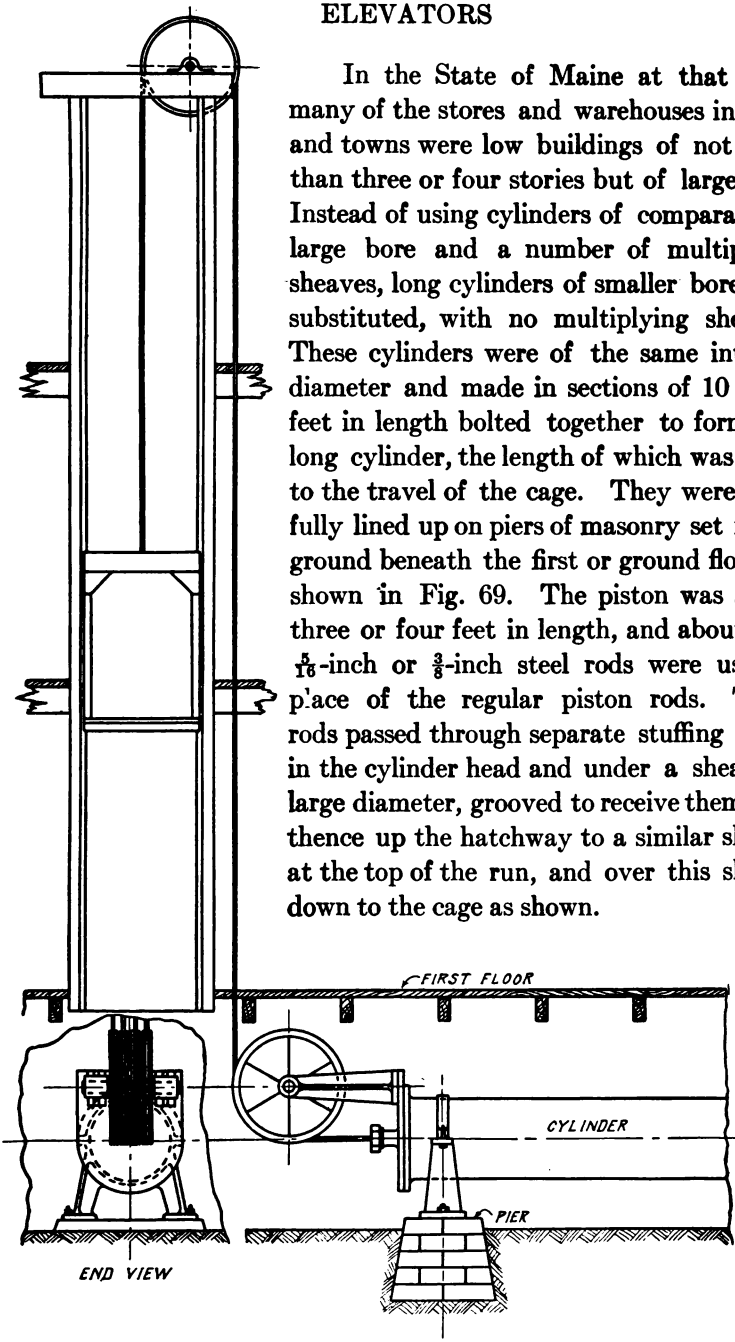


Fig. 69. Early New England Type of Low-Pressure Hydraulic Elevator

These rods, or wires, were moderately flexible and would readily bend around a 4-foot sheave, without danger of becoming crystallized and cracking for some time, and enough of them were used to insure the necessary tensile strength. No counterweight was used to offset the weight of the car, as it was believed that all the weight of the empty cage was necessary to overhaul the long heavy piston. The valve was the one which has just been described.

These machines were not available as vertical engines on account of the extreme length of cylinder required and because the available water pressure would not always carry the supply as high as the top of the cylinder. In practice, these machines were a disappointment. It was found that, owing to their diminutive size and the speed at which they traveled, the piston rods out not only the packing but also the stuffing boxes very rapidly. It was also impossible to lubricate either the pistons or the cylinder, which were inaccessible, and as a result they became leaky and wore out quickly. The steel wires crystallized and cracked much sooner and more often than was anticipated. Passing notice is given this machine only because of its novelty and the experience it afforded.

Hale Water-Balance Elevator. About the year 1869 or 1870 Mr. William E. Hale patented and introduced a machine, known as Hale's Water-Balance Elevator, which in many particulars greatly resembled the one just described. The novelty of this machine was that it utilized the force of gravity for its operation.

Construction. At the top of the run, one or more sheaves mounted in the customary manner spanned the distance from the center of the hatchway to the center of a large tube about 3 feet or more in diameter, as shown in Fig. 70. This tube extended from this point to the ground, being run as closely adjacent to the hatchway as possible. The lower end of this tube terminated in, or connected with, an underground tank. On the roof directly above this tank were another tank and a steam pump which pumped water from the lower to the upper tank through suitable piping. Over the sheaves at the top of the run was the usual cable, to one end of which was attached the traveling car and to the other end a large metallic bucket.

Brake. The cage, in addition to the usual guideways, was supplied with a powerful brake actuated by strong steel springs

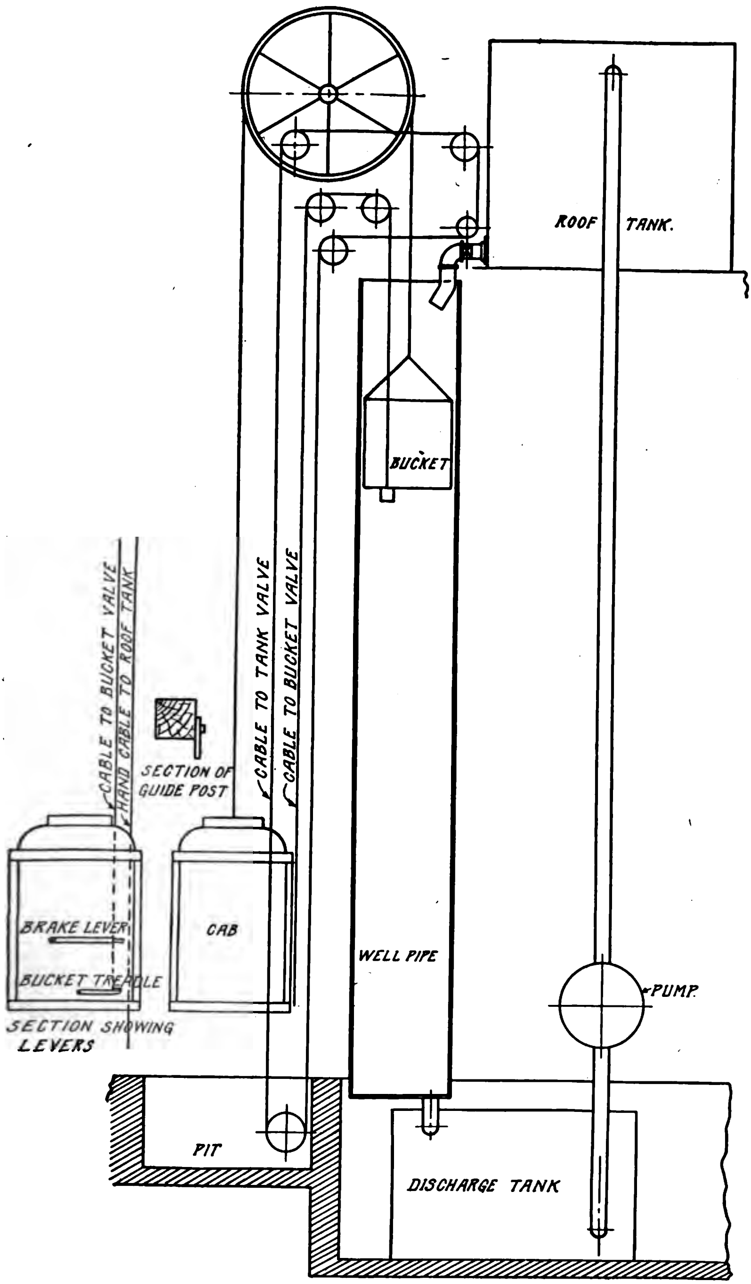


Fig. 70. Diagram of Hale Water-Balance Hydraulic Elevator

which, when left to themselves, automatically applied the brake to the guides. The guides were long, thin, flat bars of steel about ½ inch by 6 inches, bolted to one side of the guide post, which was of wood, the steel plate projecting about 3 inches beyond the post to form a guide for the car and to present a suitable surface for the long brake shoes to act upon. This brake also served as a safety device. It was released with considerable effort by means of a lever located inside the car.

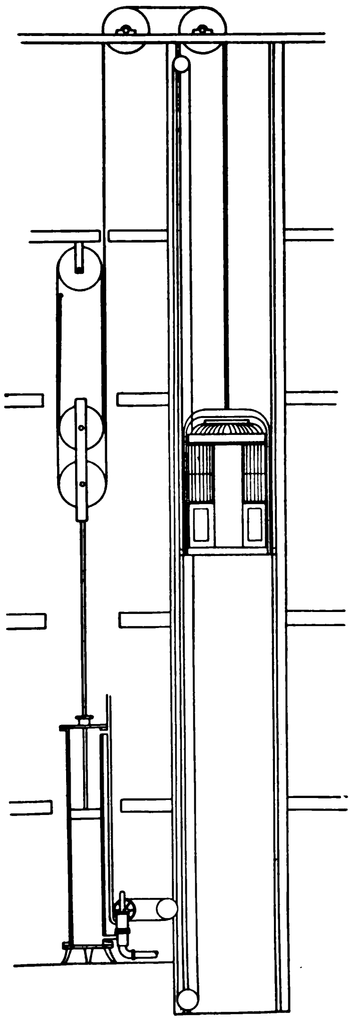


Fig. 71. Diagram of Hale Standard Hydraulic Elevator

Operation. At the bottom of the roof tank and directly above the metallic bucket there was a large valve which was actuated from the cab by means of a hand cable. In the bottom of the bucket was a similar valve with which communication was had by means of a foot lever in the cab. When it was desired to cause the elevator to travel upward, the brake was released and the valve in the upper tank was opened. Water was permitted to flow into the bucket until its weight caused it to descend, pulling the cab upward. The stops at the intermediate floors were accomplished by means of the brake.

The descent was accomplished in a similar manner, the water being let out of the bucket into the well from whence it flowed into the underground tank, to be pumped to the roof tank again.

Speed. The speed of this elevator was remarkable. It exceeded that of any elevator that had been made up to that time. Its lifting capacity was limited only by the weight of water the bucket would hold and the strength of the materials entering into the composition of the machine. If the guides were accurately lined up, its operation was smooth. It required skill and experience, however, to operate it and the cost of installation was also high. These were doubtless some of the causes contributory to its eventual abandonment.

Hale Standard Hydraulic. Another vertical hydraulic elevator manufactured by William E. Hale, and introduced three or four years after the advent of the water-balance type, was what he afterward designated as his "Standard Hydraulic". It was simply a vertical hydraulic elevator, Fig. 71, similar to the Armstrong elevator when made with the cylinder vertical, except that it used a circulating pipe which permitted the water, after it had been used above the piston, to be returned during the succeeding stroke to the under side of the piston. This feature, which was found in practice to be essential to its successful operation, was originally introduced for a different purpose.

Efforts to Obtain Economy of Water. Many makers of hydraulic elevators had for years been trying to devise means for economizing in the use of water for operating these machines. High pressures had not been tried to any great extent, the efforts toward this end being principally directed toward using the water discharged from the cylinders for other purposes, principally that of storing it in tanks from which it could be drawn for use in lavatories, etc.

Armstrong Three-Cylinder Machine. Armstrong had made a three-cylinder machine, the piston of each cylinder being attached to the same crosshead. For light loads he admitted water to one cylinder only—the central one; for medium loads to the two outside cylinders only; and for heavy loads to all three. The result was no marked success, the valve motion being too complicated, and the friction of the three pistons detracting greatly from the efficiency of the machine.

Fensom Balancing Device. John Fensom of Toronto, Canada, had developed the scheme of using a circulating pipe connecting the front and back ends of a horizontal machine in such a way that the water, after being used for hoisting, was discharged on the lowering trip into the other end of the cylinder, and then on the next up-trip was forced into overhead tanks for use about the building.

To take care of the heavy loads, he set the bearing boxes of his overhead sheave on the end of a lever pivoted on knife-edges similar to those used with the levers of large platform scales. The long end of this lever was weighted to suit the loads as shown in Fig. 72. When a heavy load was placed on the car or platform of the elevator, it would lift the long end of the lever, having overbalanced it and the weight attached. The long end of this lever had connected to it a small cable or a thin rod running down to a pipe laid underground and connected to the sewer. This rod or cable was attached to a valve set in the pipe and when, through an overweight on the platform, the lever was raised, it opened the valve in the pipe and allowed the discharge water to run to waste, thus relieving the

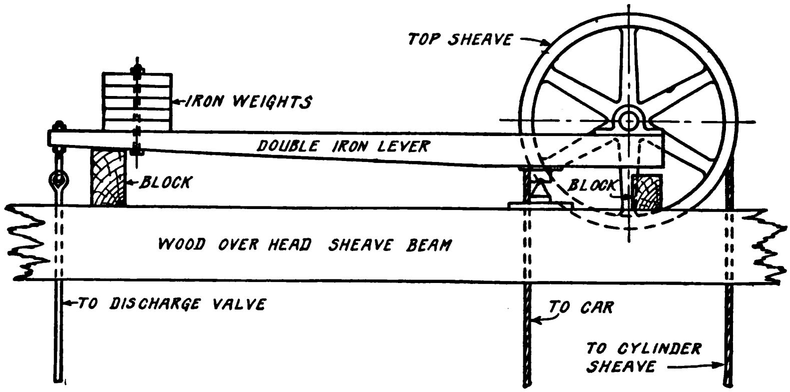


Fig. 72. Fensom Balancing Device

piston of back pressure and allowing the elevator to lift the heavy load. Hence it was only while lifting light and medium loads that water was economized.

It was found in practice, however, that the discharge water from these machines, owing to the necessarily frequent use of lubricating oils inside the cylinders, was too foul and greasy to be suitable for any other purpose and the idea was abandoned.

Baldwin's Efforts. The inventor of the Hale standard hydraulic, Mr. Cyrus W. Baldwin, had in view the idea of water economy when he invented that machine. He, however, labored under greater disadvantages than did Mr. Fensom. He soon found that his scheme of economizing water was not only a failure but that, owing to universally lower pressures in the territory in which he operated, he was unable to force the discharge water into reservoirs and that in order to obtain a uniform piston pressure throughout the entire stroke he had to retain the circulating pipe and return the water to the under side of the piston to enable him to maintain this uniform pressure. Moreover, a perfect circulation of water could not be insured if his cylinders exceeded 32 feet in height, owing to the fact that a column of water 33.94 feet exerts a pressure equal to one atmosphere or 14.7 pounds per square inch.

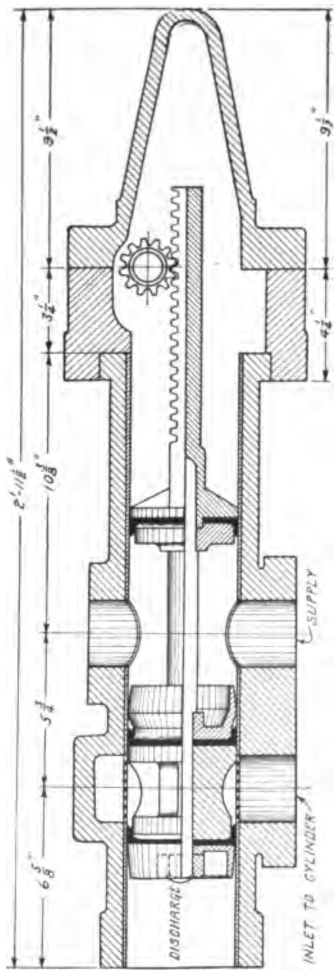


Fig. 73. Section of Hale Operating Valve

Hale Valve. The Hale operating valve, Fig. 73, was identical in design and construction with that used with the other types of elevators, but it was connected differently. In the Hale standard hydraulic elevator, the piping was so arranged that the pressure of the feed water was always on the piston. The hoisting was done by opening the discharge end of the valve, Fig. 74, and allowing the water below the piston to flow away to the sewer or discharge tank, as the case might be. As the water beneath the piston flowed away, the piston would follow it, having the pressure of the feed water above it and the weight of the column of water below, both forcing it in the same direction. In lowering a load, communication was opened between the upper and lower ends of the cylinder. The pressure was then equal on both sides of the piston and the car descended by gravity. In doing so it displaced the water in the cylinder from the top to the bottom side of the piston through the medium of the circulating pipe.

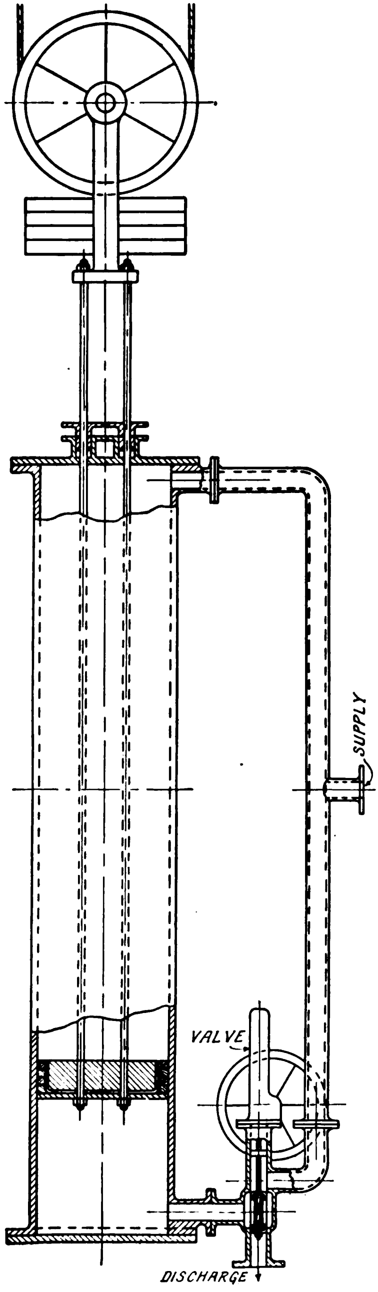


Fig. 74. Diagram Showing Operation of Hale Elevator

Piston Packing. The packing for the pistons of all these earlier elevators was similar to that used in the valve, i.e., a leather cup, but was much larger. So large were cups made that an entire hide of leather was often required to make one.

The comparatively rapid motion of the piston and the distance it traveled in a given time, especially in those elevators with a gear ratio of only 2 or 3, wore out this packing very quickly. The frequent renewals required and their tedious and expensive nature soon caused the introduction of other forms of packing. In some cases several rings of plaited hemp were used, the piston being turned to receive them. They were kept in place and tightened up when leaky by a follower ring held in place by bolts or by studs and nuts. In other cases, round and square cords of India rubber, set in alternately, or alternate rings of round rubber cord and square plaited hemp were substituted for the hemp packing first mentioned, each type having its advocates.

Hale's Hemp Packing. One of the best of these piston packings was that devised for the Hale elevator. This was a combination of the leather cup and the square hemp or canvas packing, Fig. 75, the latter being so arranged that it rubbed against the bore of the cylinder and took all the wear. The leather cup, being disposed inside these rings and receiving the pressure of the water on its inside, forced the packing out of place but was not of itself subjected to any wear. This packing required no setting up and was automatic in its action until the rows of canvas packing were worn beyond usefulness.

Siphon Relief. *Necessity for Counterbalancing Adjustment.* At this time the counterbalancing of elevators had not received the attention that it has since. It was impossible to counterpoise these machines except from the cage or car, and then not up to the entire weight of the car because a certain preponderance on the car side had to be allowed in order to enable it to overhaul the lifting cables and move the piston so as to descend when empty.

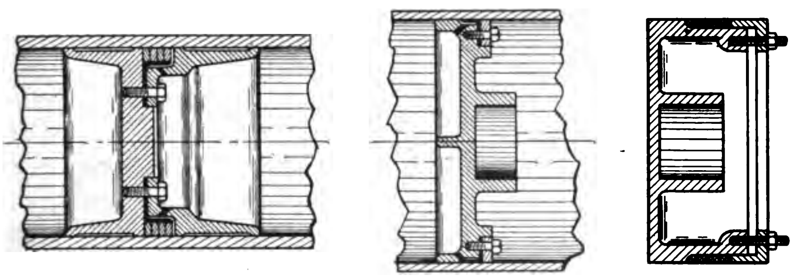


Fig. 75. Section of Piston, Showing Hale Hemp Packing in Place

In addition to this the safeguards around hatchways, except in the case of passenger elevators, were not what they are today. Most freight hatchways were open, with only a simple bar or two around them at a height of two to four feet to prevent persons from walking into them. For this reason, it frequently happened that goods were either piled on the floors or inadvertently left projecting slightly into the hatchway so there was danger that they might catch and block the car in its descent. When this occurred with the Hale machine, nothing further happened, and when the obstruction was removed the car simply continued its descent exactly as it was doing when interrupted. A glance at the illustration of the Hale cylinder and circulating pipe, Fig. 74, will make this clear.

With the horizontal cylinder it was different. Upon the car being stopped by an obstruction in its descent, all the water in the cylinder would run out into the sewer or discharge tank. When the obstruction was removed from below the car, unless water had first been re-admitted to the cylinder sufficiently to lift it, the car would drop to the bottom of the runway, causing damage to the cables, sheaves, crosshead, or piston and cylinder head, or to the car itself, if no other casualty occurred.

Construction. To prevent this the "siphon relief" shown in Fig. 76 was introduced. This was simply a siphon set in the dis-

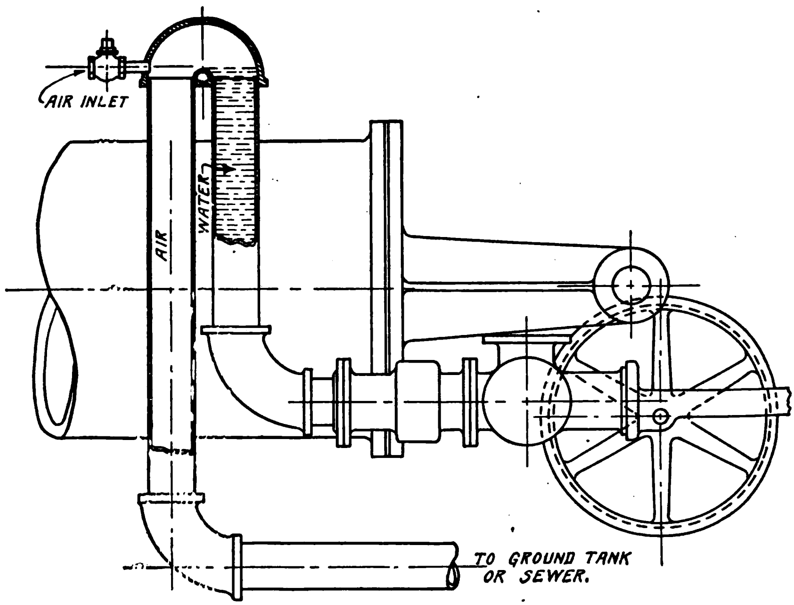


Fig. 76. Diagram of "Siphon Relief" Device

charge pipe between the valve and the sewer or tank, the upper end or bend of which was above the top side of the cylinder. In this upper bend a small check valve opening inward was inserted, and when any obstruction of the car relieved the water in the cylinder of the pressure which was forcing it out, the admission of air through the check valve, which at once occurred, would allow the water in that leg of the siphon connecting with the sewer or underground tank to flow away, while the water remaining in the other leg would balance what was left and prevent any further outflow.

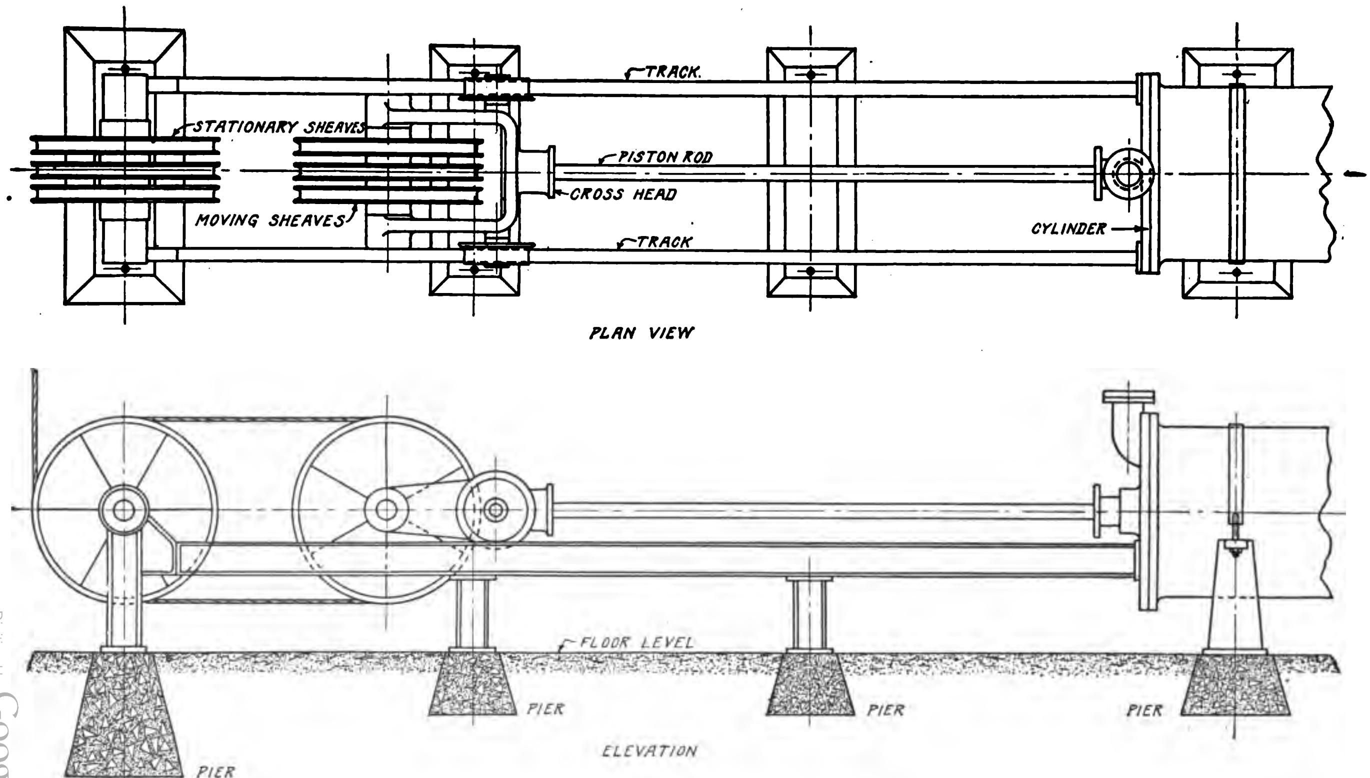


Fig. 77. Horizontal Cylinder "Pull-Type" Hydraulic Elevator

Pull Machines. The first hydraulic elevators made in the United States were all so built that the two sets of sheaves were pulled apart in order to produce the movement which caused the elevation of the car, Fig. 77. This form of construction had its disadvantages, the most conspicuous of which was the closeness of the two groups of sheaves when the car was at its lowest point in the hatchway.

Pulley and Cable Arrangement. The arrangement of the sheaves and cables on any one of these elevators, whether it be vertical or horizontal, is identical with the arrangement of the sheaves and rope in a tackle used in hoisting heavy loads by hand except as to the point of application of the power and of the load. When pulley blocks and a rope move a heavy load by hand the power available is limited—in fact, the object of the machine is to allow a small power to lift a heavy weight. Consequently, the load is applied to one end of the tackle, which is so arranged that a mechanical advantage is obtained. If four frictionless sheaves are used, a man can lift a weight four times as great as the force he exerts. However, the weight will be lifted through only one-fourth of the distance through which the free end of the rope is moved. In practice this is not strictly true, for friction has to be subtracted from the theoretical weight which it is possible for the system to lift.

With the hydraulic elevator the conditions are reversed. In this case there is an abundance of power. By applying this power directly to the sheaves and attaching the load to be lifted to the free end of the tackle, the large amount of power is so distributed as to lift a smaller load through a correspondingly greater distance.

Two sets of sheaves are used as in a rope-tackle action. One set is fastened to fixed supports while the other set is located in a crosshead attached to the end of the piston rod, as shown in Fig. 78. This crosshead is fitted with a pair of small flanged truck wheels which run on a track comprised of two iron rails set in line with the bore of the cylinder and at one end of it.

When water under pressure is admitted to the cylinder it forces the piston along its bore and, through the medium of the piston rod to which it is attached and the crosshead, it pulls the set of movable sheaves away from the set of fixed sheaves. The hoisting cable is attached at one end to the frame which holds the fixed sheaves and is wound around one of the sheaves in the crosshead. It is then passed underneath to one of the fixed sheaves, then around, over, and back to the second sheave in the crosshead, the process being continued with all the sheaves, the cable finally being carried up the hatchway to the sheave at the top of the run, over it, and down to the car. When the piston moves, the car moves a proportionately

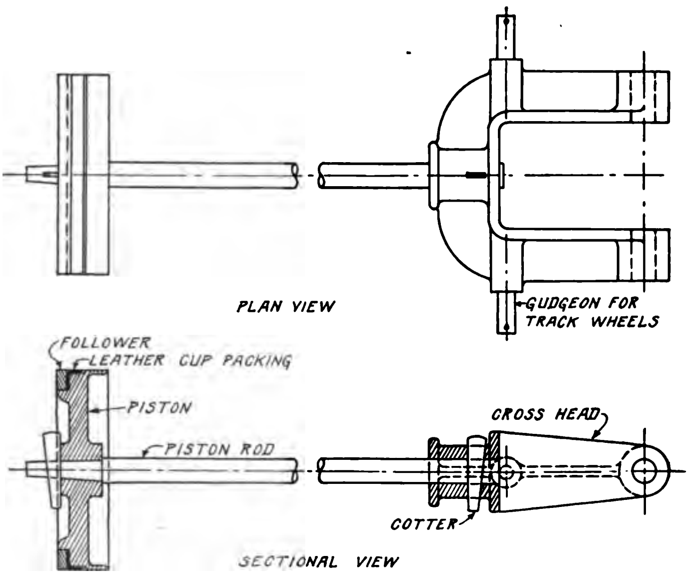


Fig. 78. Details of Piston and Crosshead for Pull Machine

greater distance, depending upon the number of sheaves that are used.

Multiple Sheaves. If eight sheaves are used, four fixed and four movable, the car will move through eight feet while the piston moves one foot. This is called the "multiple" of the machine. Similarly, the car will lift only one-eighth the load corresponding to the pressure applied to the piston. This, however, is only theoretical, as frictional losses will somewhat reduce the load the car can lift. Suppose the piston is 24 inches in diameter and has an area of 452 inches. With a water pressure of 50 pounds per square inch, this would give a pressure on the piston of 22,600 pounds. Let the friction in this machine be assumed to be 25 per cent. Deducting

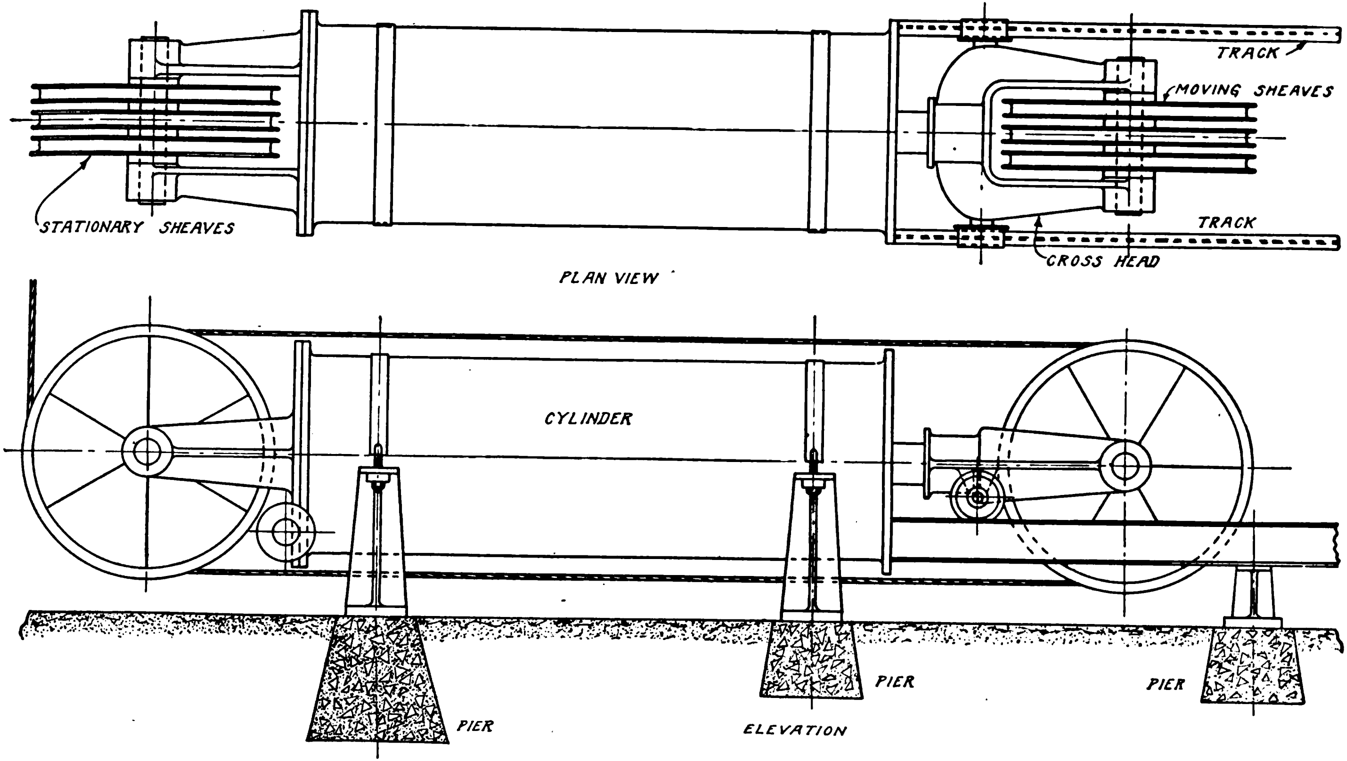


Fig. 79. Horizontal Cylinder "Push-Type" Hydraulic Elevator

the frictional loss leaves 16,950 pounds as the effective pressure. This pressure divided by eight equals 2118 pounds, the load which the machine will lift at the free end of the cable. Let it be assumed that the car weighs 1400 pounds and that it is counterbalanced to within 500 pounds of its weight, this 500 pounds of unbalanced weight being left for the purpose of enabling it to overhaul the cable and move the piston in descending. This 500 pounds must be deducted from the 2118 pounds, leaving 1600 pounds as the load which can be lifted in the car. This compared with the actual pressure on the piston seems small indeed, but it must be borne in mind that the car moves eight times as far as the piston does. While the piston is moving, say, ten feet the car moves eighty feet.

Disadvantage of Pull Machines. Owing to the construction of the pull machine, the two sets of sheaves were necessarily very close together when the car was at the lowest point of its travel, and as the cable passed from one sheave to the other it did not lie parallel with the center line of the bore of the cylinder but at a considerable angle. This feature caused a certain amount of friction and, in addition, chafed the cable when it entered and left the grooves of the sheaves. Of course, when the two sets of sheaves were farther apart, the angle became less acute and the consequent wear and friction was lessened.

Push Machine. To remedy this defect, the "push machine", Fig. 79, was devised. In this machine the set of fixed sheaves was attached directly to the cylinder head, which was moved up closer to the hatch to allow these sheaves to lead up in the hatchway as before. The piston rod was attached to the opposite side of the piston and passed out through the open end of the cylinder, thereby obviating the need of a stuffing box and eliminating another source of friction. The piston rod was made thicker, Fig. 80, because it was now to have a compressive strain instead of a tensile strain as previously. The track on which the crosshead was to travel was also set to lead away from the open end of the cylinder, as can be seen in Fig. 79. With this arrangement the two sets of sheaves never got closer together than the length of the cylinder and hence the acute angle for the cables was eliminated. This machine eventually became the most popular of the horizontal type, though in both the horizontal and the vertical types it had serious defects.

Use of Multiple Cables. If the cable of the vertical or Hale machine broke, the heavy crosshead with its moving sheaves would bend over and buckle the thin long piston rods. If the stuffing boxes at the top of the cylinder began to leak badly, or if the circulation pipe broke, the lower stories of the building would be flooded with water. To prevent the damage done by the breaking of the hoisting cables, from two to six cables were used, it being supposed that not more than one, or at the most two, of these cables would break at once.

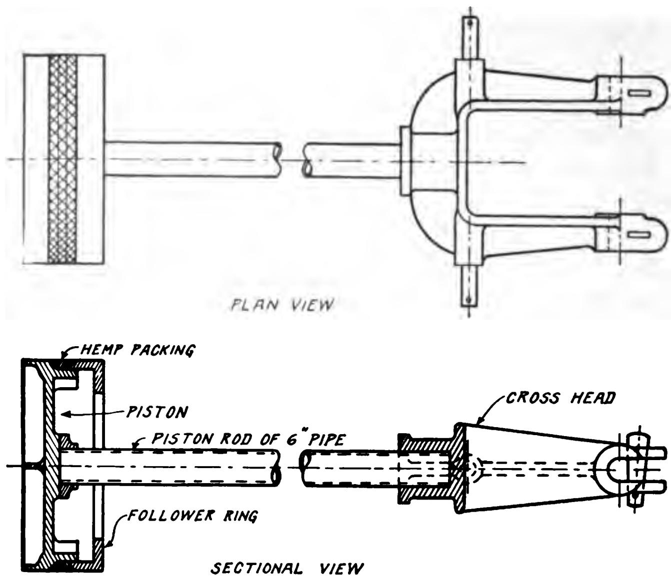


Fig. 80. Details of Piston and Crosshead of Push Machine.

This feature was recognized as a safety device, and two hoisting cables instead of one were adopted on all types of drum elevators. Not more than two cables were used on the drum or winding machines because of the immense length of drum required, but on the horizontal as well as on the vertical hydraulic machine, four and even six cables for passenger machines became customary. It was found that an excessive number of cables on a hydraulic elevator increased the total friction sometimes as much as 45 and even 50 per cent of the input of power.

AUXILIARY DEVICES

Up to this time the only method of limiting the travel of the car or, in other words, of stopping it automatically at the end of its travel at the top and bottom landings, was by means of the operating cable.

Stop Buttons. On this cable, at the proper distances from the lower and upper landings, were clamped balls called "stop buttons", Fig. 81. These buttons were made in halves, which were joined or attached to each other by bolts used for clamping them to the cable. An arm, one end of which was attached to the car and the other terminating in an eye, was made to travel up and down on the operating cable the full length of the run. When this eye, in the course of its travel, came in contact with the stop button, it would move the cable in the direction in which the car happened to be going, thereby closing the valve and stopping the machine.

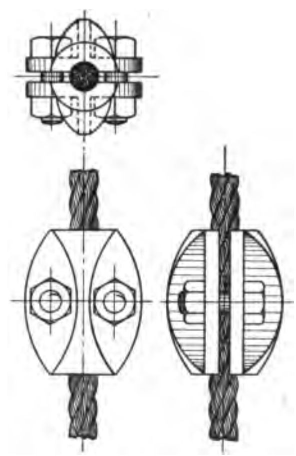


Fig. 81. Details of Stop Buttons

Protection Not Adequate. But if the operating cable should break, through wear or through having been exposed to water at the bottom of the pit, there was nothing to prevent the piston continuing its travel until it passed entirely out of the cylinder. Hence the cellar would be flooded, for the valve being still open, a stream of water would continue to flow out through the open end of the cylinder until the valve was closed by hand. The same thing would occur if the stop button slipped, as it sometimes did. It would also happen if the hoist cables broke or became displaced from their respective sheaves, as sometimes happened with high-speed elevators when stopped suddenly.

Another disagreeable feature, in case the operating cable or valve mechanism became deranged, was that if the top of the car hit the upper beams, which carried the top sheaves, before the piston left the cylinder, the constant and terrific pull which the cables would receive was apt to strain or rupture the fastenings.

These defects were confined to the horizontal machines, and did not exist in the Hale vertical machine, because both ends of the cylinder were closed. If the operation of the Hale machine became deranged, the piston would stop on reaching the cylinder head and all strains due to the pressure of the water against the piston were confined to the cylinder itself and no harm was done. These troubles with the horizontal machine led to the use of the *cable guard* and the *limit valve.*

Cable Guard. Fig. 82 shows the cable guard, which was simply a frame for holding three rods at right angles to each other close to the faces of the sheaves, so as to make it impossible for the cables to escape from their respective grooves.

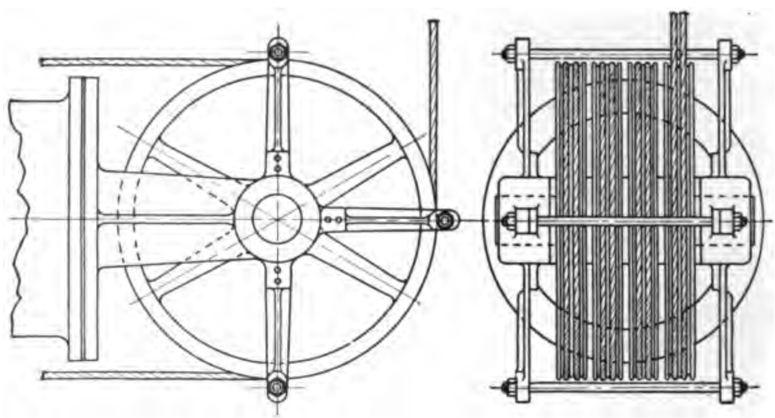


Fig. 82. Cable Guards to Prevent Slipping of Cables from Grooves

LIMIT VALVES

The limit valve was made auxiliary to the operating valve and was placed between it and the cylinder, Fig. 83, being operated by the motion of the piston rod. The use of the limit valve necessitated a slight change in the addition of another port in the operating valve for discharging water, and an extra leather cup to control this port.

Early Types. Various forms of limit valves were devised. One of the earlier types for a pull machine and one that was in general use is shown in Fig. 84. In this illustration it is in the neutral position; that is, the passage is open for running in either direction, the piston being about midway in its stroke. When the piston arrived at the end of its travel in either direction, it would, through appropriate intervening mechanism, close the passage for water in that direction, thus stopping the piston and making it impossible for it to receive any more water, regardless of how the operating valve might be manipulated, but the way was left open for the passage of water to allow the piston to move the opposite way. The methods of bringing this about were numerous; some were very simple, while others were more or less complicated.

Operating Mechanism, Pull Machine. One of the simplest was that in use with the pull machine. In this case, the valve stem was lengthened to a point slightly beyond the end of the crosshead guide rails. To the crosshead was attached a strong arm with

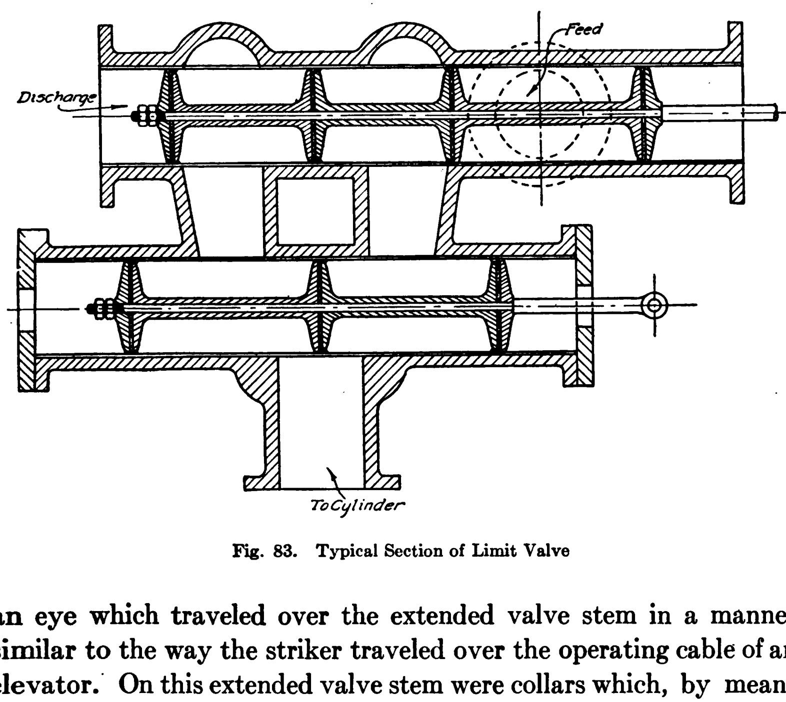


Fig. 83. Typical Section of Limit Valve

an eye which traveled over the extended valve stem in a manner similar to the way the striker traveled over the operating cable of an elevator. On this extended valve stem were collars which, by means of set screws, could be adjusted to any position desired. Being set and fastened in their proper position, when the arm attached to the crosshead reached either collar it would move the valve stem slowly along with it. This would close the valve and cut off the supply of water, consequently stopping the piston movement, but leaving the way wide open for it to go in the other direction. Spiral springs were provided which were so adjusted as to always

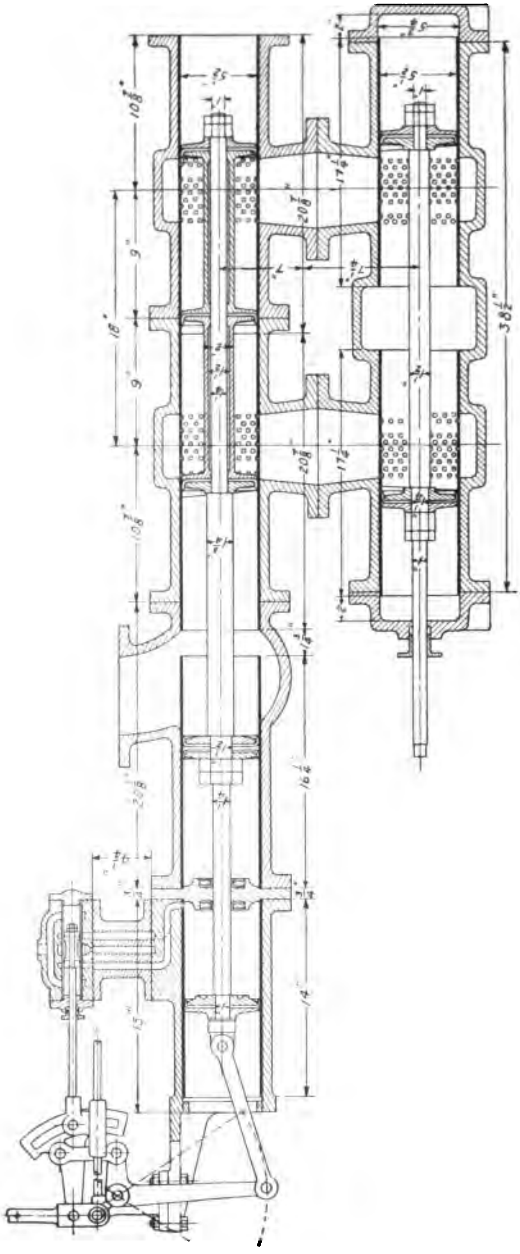


Fig. 84. Early Type of Limit Valve for Pull Machine

return the valve to the neutral or middle position, when the piston was moved in the opposite direction.

Operating Mechanism, Push Machine. Fig. 85 shows another method of operating the limit valve applicable only to the push machine. It comprised a channel or grooved way *A*, made with clamps *C* for its attachment to the piston rod and having its ends turned up and down, respectively, at an angle of 45°. In this groove ran a roller *D* on a pin fastened at the end of a vibrating arm keyed on a rockshaft, which worked in a bearing *B* bolted to the end of the

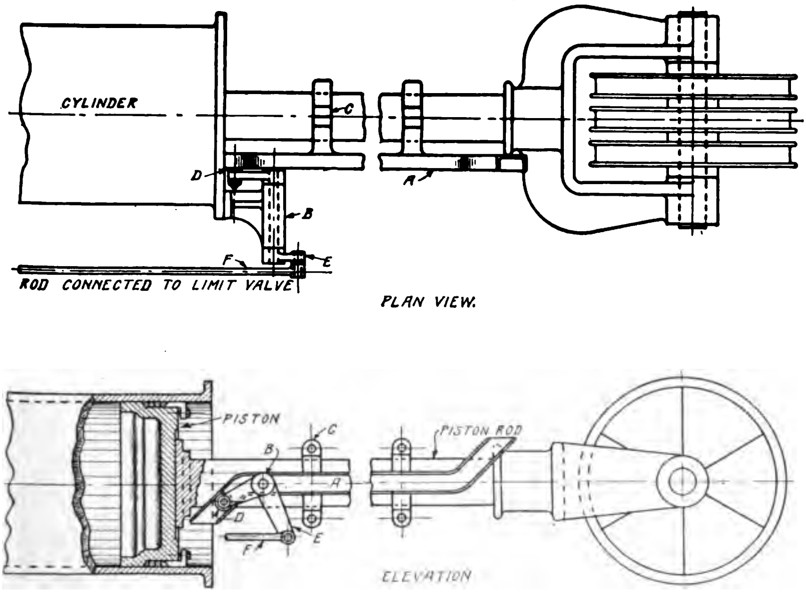


Fig. 85. Operating Mechanism for Push Machine

cylinder. At the other end of this rockshaft was another vibrating arm *E*, to which was attached the rod *F*, which opened and closed the limit valve. When the piston was in mid-stroke, the roller would be in the straight part of the channel *A*, and the limit valve would be either in the central position or open both ways, so that the engine would be free to run in either direction; but when the piston reached one end of its stroke, the arm would be deflected up, and down when it reached the other end, thus causing the valve to be closed for either the up or down motion as required.

Whittier Limit Valve. Another form of limit valve was used with the Whittier pull machine and was simply a form of stopcock inserted between the operating valve and the cylinder. It did not close the pipe completely, but simply choked off the supply of water, allowing the piston to move very slowly at the end of the stroke until it was stopped by an obstruction bolted to the open end of the cylinder at one end or by the cylinder head at the other limit.

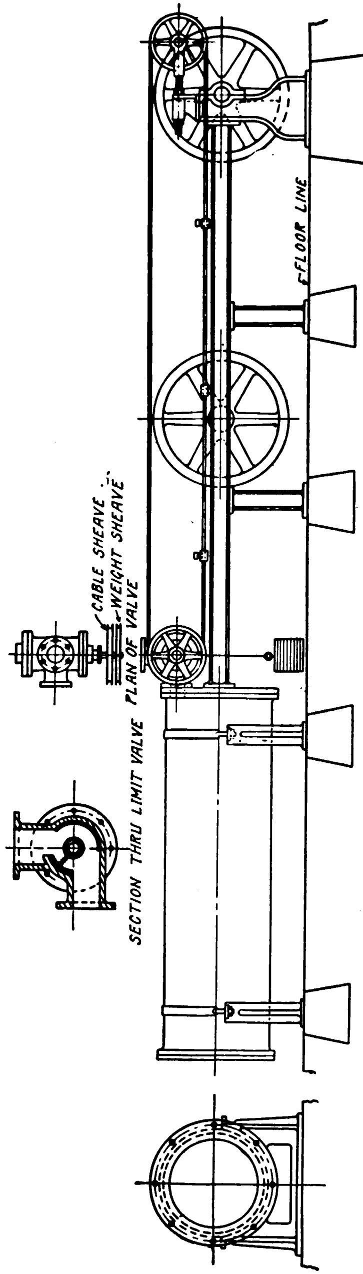


Fig. 86. Hydraulic Pull Machine Fitted with Whittier Limit Valve

Operating Mechanism. It was operated by a very primitive device, Fig. 86, which was similar to the operating cable and striker already described, except that in this case the striker was attached to the crosshead and the operating cable was attached to a sheave on the valve stem and was carried around an idler sheave at that part of the track farthest from the cylinder. Stop buttons were attached to this cable for the striker to impinge on and thus close the valve, which, upon the return of the piston, was opened by a weight attached by a short chain to another sheave on the valve stem, and so arranged that whichever direction the valve stem was rotated caused the chain to be wound up and the weight lifted, the latter returning

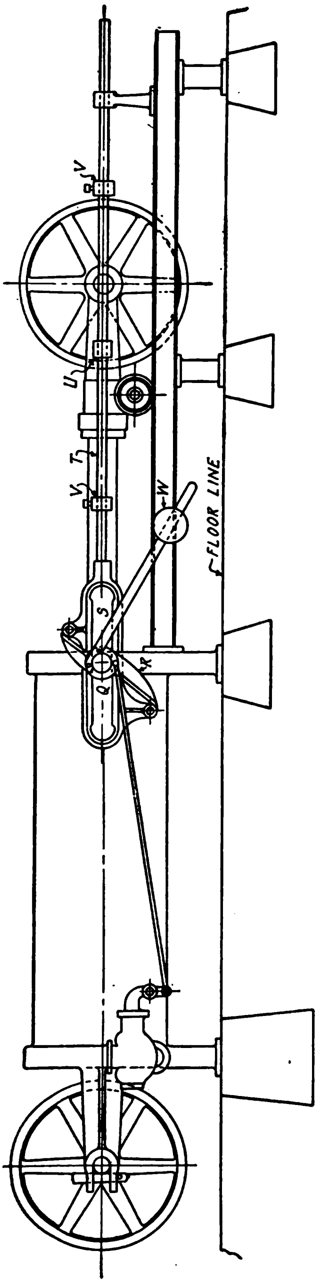


Fig. 87. Hydraulic Push Machine Fitted with Crane Limit Valve

to its original position as soon as the power which lifted it was relaxed.

Crane Limit Valve. Another limit valve, that of the Crane Company of Chicago, will make the list large enough to give a good general idea of the principles and construction of this feature of the hydraulic elevator. The operating mechanism, Fig. 87, resembles the Whittier in that it does not completely shut off the ingress or egress of water to or from the cylinder, but merely chokes it, and the initial start-up in either direction is effected by the water which leaks through the limit valve, when the operating valve is opened. The actual stoppage of the piston is brought about by its coming in contact with a barrier placed to resist its further travel, so that the entire strain is received by the cylinder, reinforced, however, in this case by bolts and crossbars.

Fig. 88 gives a clear idea of the Crane horizontal machine. It is a sectional plan of the cylinder, piston, and crosshead of the Crane push type of horizontal machine, with its reinforcing bars across each end. Those at the closed end are cast as part of the cylinder head while that at the open end is a separate piece, perforated in the center for the passage of the piston rod and held in place by two strong bolts on each side of the cylinder and extending their entire length. The piston and crosshead each have a recess cast in their hubs to receive a rubber ring *A* which acts as a bumper to lessen the shock of impact. The very nature of this arrangement necessitates the making of the cylinder of the exact length to suit the travel of car and the ratio of gearing, no material change being possible after the installation is once made.

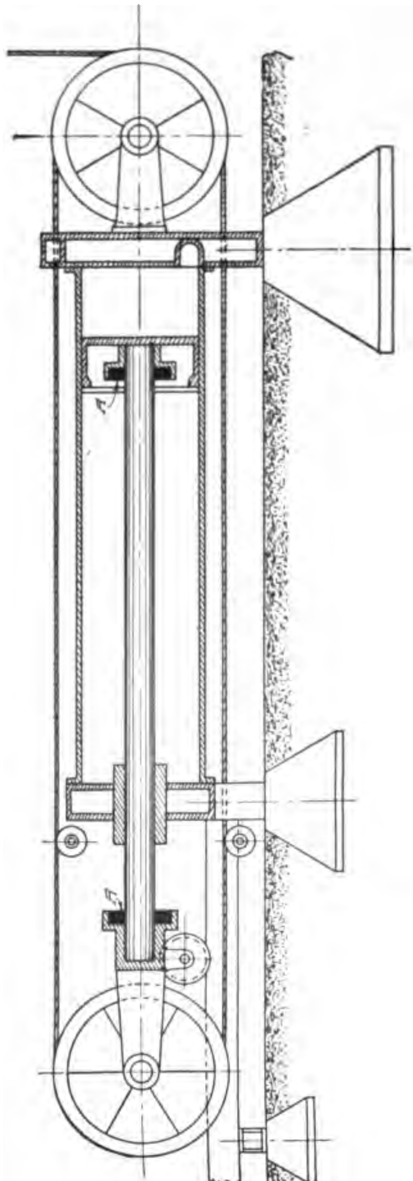


Fig. 88. Details of Cylinder and Piston Arrangement of Crane Machine, Showing Rubber Bumpers

Operating Mechanism. Several types of limit valves are shown in Fig. 89. The Crane limit valve is shown in section in Fig. 89*a* and the operating mechanism has already been referred to in Fig. 87. The valve stem is operated by a rock arm, the upper end of which works in a link or yoke in the end of the valve stem. The lower end of the rock arm is operated by a rod connected to another rock arm *R*, which vibrates on a pin attached to the side of the cylinder at the open end. On this pin, sliding horizontally, is a frame or long link *S*, from one end of which extends a rod or shaft *T* running full length of the track on which the crosshead travels. To the crosshead is attached an arm *U*, which resembles that in the Whittier machine, Fig. 89*b*, and with a similar office, namely, to strike the collars *VV*, which are on the shaft *T*. These are so set that the arm *U* will strike either one of them as it approaches the limit of its travel at either end of the stroke, the

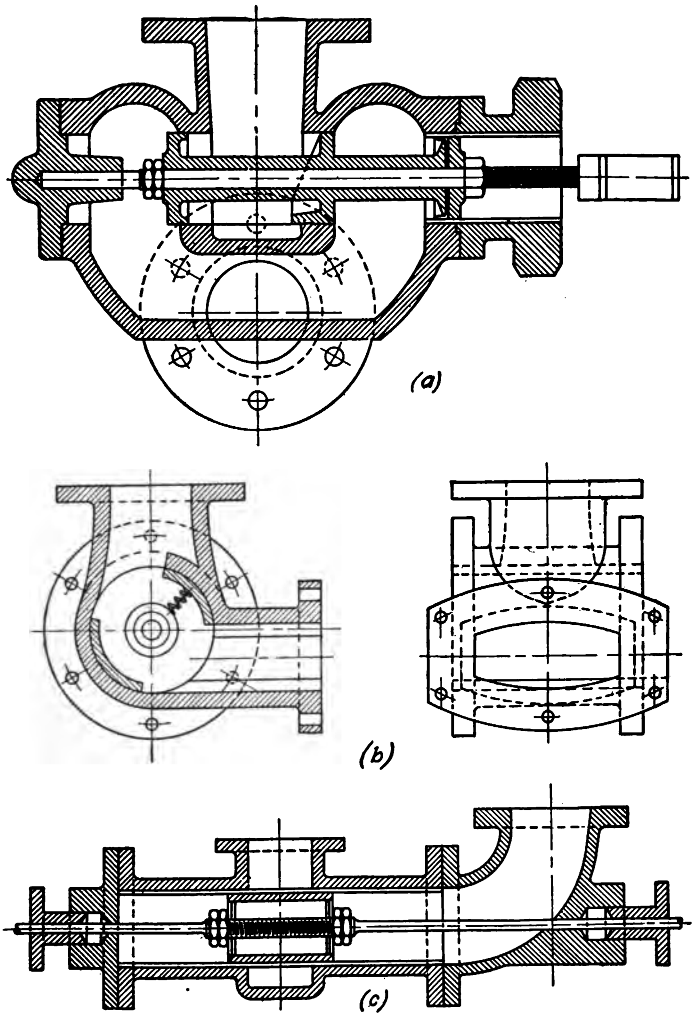


Fig. 89. Types of Limit Valves (*a*) Whittier Type; (*b*) Crane Type; (*c*) Moore and Wyman Type

effect being to carry the rod along with it. The open part of the link slides on the pin on which the vibrating lever or cam *R* rocks. This link has two brackets, one above and one below, which carry rollers. As this link travels along horizontally in either direction, one or the other of these rollers engages with the rock arm, the effect being to make it vibrate slightly, the vibration being always the same in whichever direction the rod moves. The action of the rock arm closes the valve and, upon the return of the piston, the weight *W* on its arm brings the valve back to its neutral position with the valve open.

This valve, like that of the Whittier machine, is not a limit valve in the strict sense of the term, but simply a retarder, diminishing the speed of the piston and lessening the shock against the real limit stop, which is the bar across the open end of the cylinder. This arrangement has the disadvantage of being very slow to start in the opposite direction, as the machine is then started only by the water which leaks through the limit valve, until the piston has traveled far enough to allow the weight *W* to open the limit valve again.

COMPRESSION TANKS

Necessity for Use. There are only a few cities in the United States where the pressure in the water mains reaches 100 pounds per square inch; in fact, 60 pounds is an unusual pressure. Hence a compression tank has to be used where a speed equalling that of the steam elevator—about 250 feet per minute—is desired. Roof tanks were frequently used, but at the time the hydraulic elevator made its appearance very few buildings were 100 feet in height and a tank placed on the roof of one of these buildings would produce a pressure of only 45 to 50 pounds in the basement.

Construction. The pressure desired was 150 to 200 pounds per square inch. The compression tank made this available. These tanks were usually made large enough to contain sufficient water to fill the cylinders dependent upon them about five times. The water in these tanks was kept under pressure by maintaining in them a large amount of air under pressure. When the tank was filled to the maximum of its designed water capacity, about one-third of the volume of the tank would be occupied by the air under pressure. The water inlet and feed pipes entered at the bottom of the tank so as to reduce the possibility of air in any considerable amount entering the cylinders and producing a jumping motion of the car in starting and stopping. However, cocks were inserted at the highest points of the cylinders to permit the letting out of air whenever it accumulated in any considerable quantity, for even without these compression tanks this difficulty was experienced because of the air contained in water from city mains.

These tanks were supplied with water by a duplex steam pump to avoid any dead point, as it was necessary for them to start up instantly at any moment. They were governed by a device called a pump governor, which was simply a disk or diaphragm of rubber reinforced by a strong spiral spring and placed in an enlargement of a pipe which ran to the compression tank. This pipe, at its other end near the governor, connected with the steam supply by means of a valve, the stem of which was attached to the center of the diaphragm. When the water pressure reached a certain height, its pressure on the diaphragm closed the steam-supply valve and the pump would stop, and *vice versa*. When the pressure in the tank fell, the spring would open the valve and start the pump again, this part of the operation being absolutely automatic so long as a suitable pressure of steam was maintained at the boilers.

These tanks were supplied also with a valve and pipe to empty them for cleansing and repairs, while to replenish the water, a surge tank was supplied, into which the water was discharged after it had been used in the cylinder. The suction pipe from the pump was led into this tank, and a small air pump was used for replenishing the air. This pump was also operated by steam but was not automatically controlled, as its services were required only every few days where all the joints and seams were tight. These tanks varied in size according to the size and number of elevators to be supplied. Those for small elevators were frequently set on end, but the larger ones were usually set horizontally in cast-iron saddles, which in turn rested on piers of masonry. Sometimes they were set on steel beams above the roof; but no particular advantage accrued to the latter arrangement except a saving of room and possibly less strain on the tank, for there was always an additional gain in pressure at the cylinder due to the height of the tank above it, but the work for the pump remained the same.

Operation. The pressure of the air was, of course, transmitted to the water, thus giving the required pressure. As water was withdrawn from the cylinder, the air would expand with a reduction in pressure. However, the water-pump governor was usually set to act under a variation of not more than five pounds in pressure. Hence, the air pressure, and consequently the water pressure, remained almost constant, the water pump replenishing the water at the end of each trip.

PILOT VALVES

Function of Pilot Valve. With the increased pressure thus obtained it was found that speeds beyond any that had been hitherto attained were possible; but it was also discovered that it was next to impossible to control the elevators at these high speeds by means of the hand rope then in use. The stops were very uncertain and irregular, especially when air, even to a very limited extent, was present in the cylinder. Efforts made to remedy this difficulty resulted in the production of a type of operating valve which was called the pilot valve.

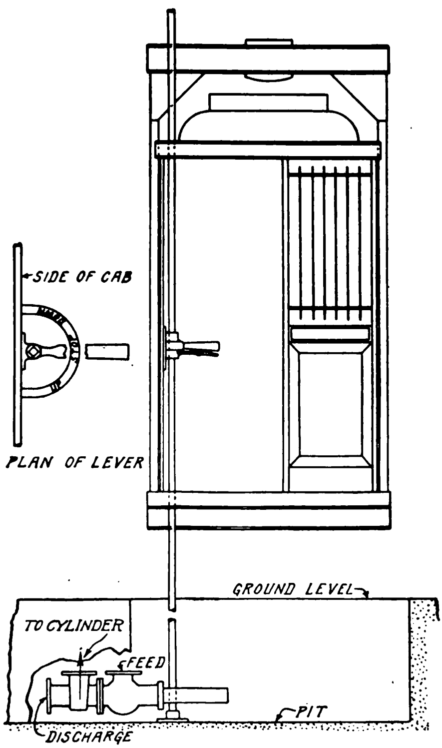


Fig. 90. First Type of Lever Control

Early Efforts. The first step in the direction of speed control was very crude and consisted in using a square shaft set vertically and running the entire length of the elevator shaft from the ground to the roof, passing through the elevator cab, Fig. 90. A forked bracket was fastened securely to the inside of the cab and between the forks of this bracket a lever was placed, with a square hole in it which surrounded the square shaft. It was a sort of box wrench and, as the car traveled up and down the shaft, this wrench went with it. By turning this wrench a corresponding movement of the shaft could be produced.

At the lower end of this square shaft a pinion which meshed in the teeth of the valve rack was fastened so that by turning this handle in the cab, the valve plunger could be made to travel lengthwise of the valve barrel and thus turn on or off the water. Attached to the bracket which held this wrench or lever was a quadrant on which were the words: Up—Stop—Down. This was to indicate to the operator which way to move the lever in order to produce the desired effect, for if the handle were moved to cover any one of these words the proper result would be obtained.

This arrangement, while a decided improvement over the hand or operating cable, still fell far short of what was desired and had

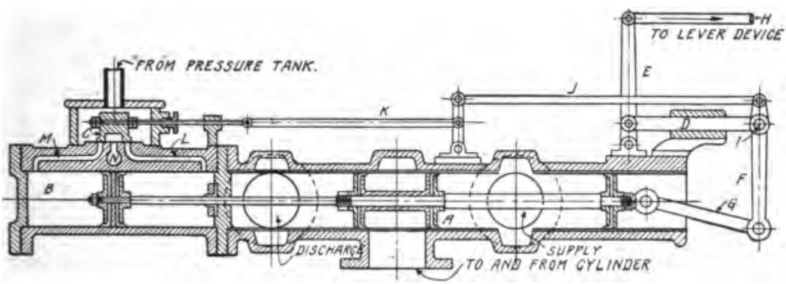


Fig. 91. Early Type of Pilot Valve

many undesirable features, the principal ones being the tendency of the shaft to bow out of the perpendicular in high runs and the friction and rubbing sensation thereby induced in the cab.

First Pilot Valve. *Construction.* The efforts of those interested resulted eventually in the production of the valve shown in Fig. 91. An examination of this device shows that it does not differ in the main body from the valves used heretofore, but that certain additions to it made its operation unique as compared with those formerly in use. The principal change was the addition of an auxiliary cylinder to the end of the ordinary valve barrel. This cylinder was fitted with a piston, the piston rod being an extension of the valve stem.

This cylinder was supplied with three ports, a slide valve, and passages for the actuating force, as in the case of the cylinder for a steam engine. The force used, however, was water from the compression tank, the ingenious and novel feature of the apparatus being the valve motion. Referring to Fig. 91, *A* is the operating valve for admitting water to, and discharging it from, the cylinder which actuates the elevator. *B* is the cylinder of the pilot valve with its piston attached to the extension of the stem of the operating valve. *C* is the small slide valve for admitting water under pressure to either end of this cylinder as desired. *D*, *E*, and *F* are levers for moving and controlling the movement of the slide valve *C*, while *G* is the connection by which the plunger of the operating valve returns the valve *D* to its normal position as soon as the plunger has reached the position it is made to assume through the movement of *E*. The lever *E* is connected to the operating lever in the cab by the rod *H* and two cables, all of which will be fully described later.

Operation. If the operating lever in the cab is in its central or "stop" position, the operating valve will be exactly as shown here in Fig. 91. Should the operating lever be moved either way, the effect will be to move *E* a corresponding amount. This will cause *D* to slide endwise through its bearing, carrying with it the valve rods *J* and *K*, thus sliding the valve *C* on its seat until it opens an end port to the cylinder *B*. Hence water under pressure will be admitted to that end of the cylinder *B*, causing the piston to move away from it. The piston, being attached to the plunger of the operating valve, carries the plunger with it and thus opens the operating valve for either the admission or discharge of water, according to the direction in which it moves.

The stem of the plunger is connected to the lower end of the lever *F* by means of the connecting rod *G*, and as it moves it carries the lower end of *F* with it. This being pivoted at *I* restores the valve *C* to its first position, covering both end ports to cylinder *B* and thus stopping the valve plunger. The operating valve remains open until the lever in the cab is restored to its central position. This in turn moves *E* back to the vertical position, but this movement slides *C* along on its seat in the opposite direction, thus opening the port to the other end of the cylinder *B* and admitting water to the other side of the piston, driving it back toward the position shown in the figure. The slide valve *C*, while it opens the end port to the pressure tank, also opens the opposite end port to the exhaust or discharge port. This allows the water used in the first movement to escape. When the plunger of the operating valve reaches its central or closed position, it has, through the medium of *G* and *F*, restored the slide valve *C* to the position shown in the illustration, thus stopping the valve movement, everything being again at rest, including the piston in the cylinder of the hydraulic engine which moves the car.

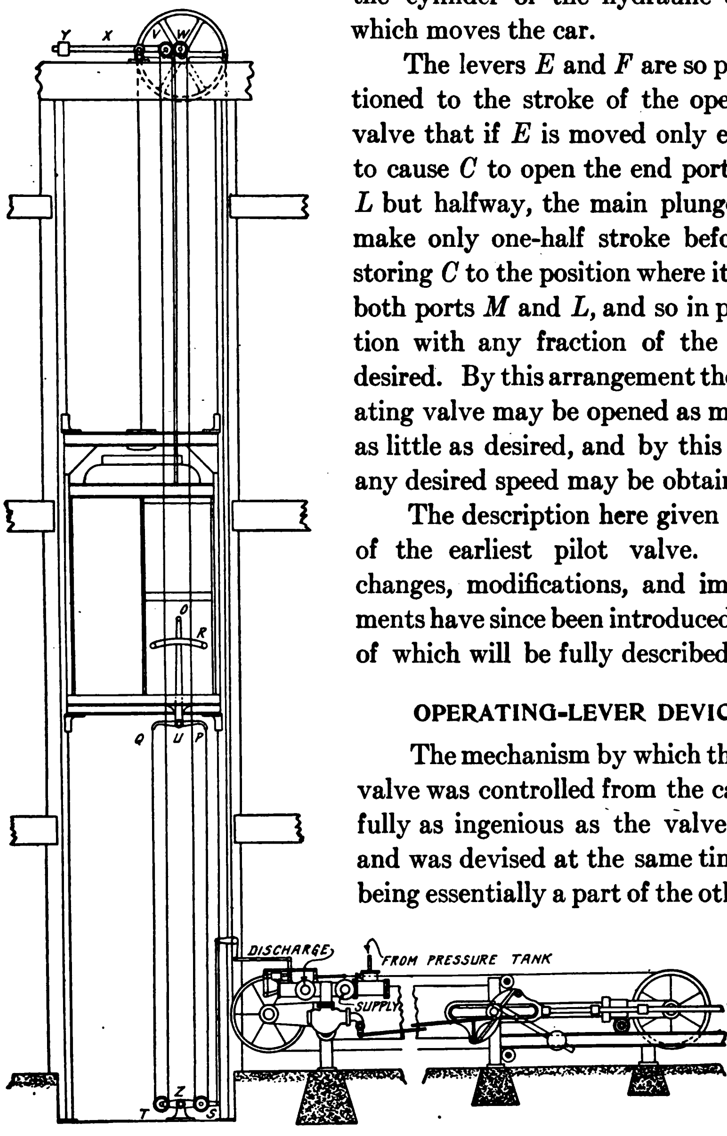


Fig. 92. Crane Operating-Lever Device. First Successful Lever Control for the Elevator Cab

The levers *E* and *F* are so proportioned to the stroke of the operating valve that if *E* is moved only enough to cause *C* to open the end port *M* or *L* but halfway, the main plunger will make only one-half stroke before restoring *C* to the position where it closes both ports *M* and *L*, and so in proportion with any fraction of the stroke desired. By this arrangement the operating valve may be opened as much or as little as desired, and by this means any desired speed may be obtained.

The description here given is that of the earliest pilot valve. Many changes, modifications, and improvements have since been introduced, most of which will be fully described later.

OPERATING-LEVER DEVICE

The mechanism by which the pilot valve was controlled from the cab was fully as ingenious as the valve itself, and was devised at the same time, one being essentially a part of the other.

Crane Type. The original idea of a lever in the cab, as previously described, was retained, but this time it was set vertically. Referring to Fig. 92, showing the Crane device, *O* is the lever by which the pilot valve is operated. If the lever *O*, which has an inverted T-shape, and which is pivoted at *U*, is moved in either direction from the

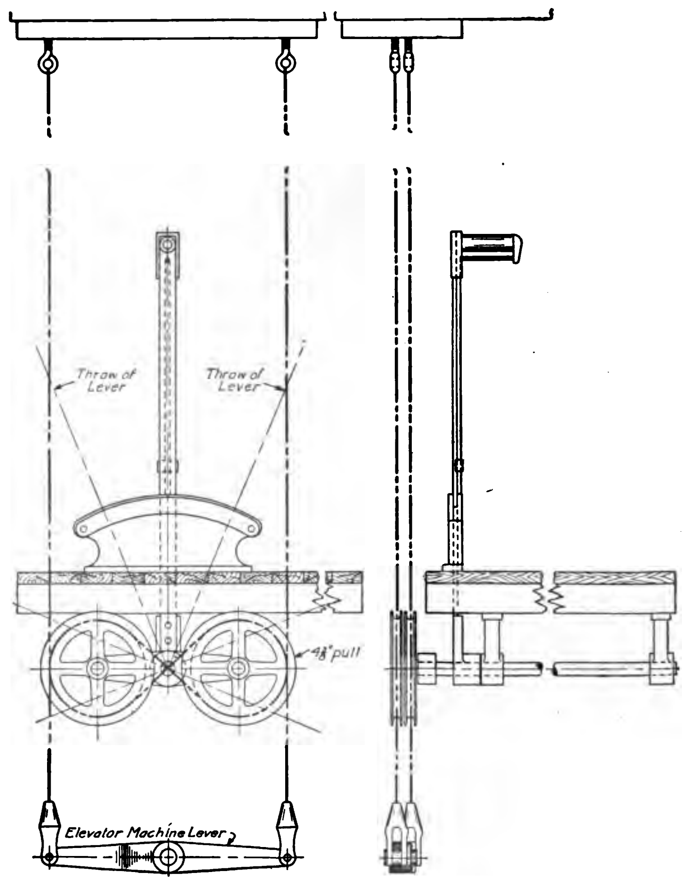


Fig. 93. Operating-Lever Device with Stationary Cables

perpendicular, one extremity of the bottom of the lever, *P* or *Q*, will be correspondingly elevated and the opposite one depressed.

From these points, *P* and *Q*, small cables are led down to and around the sheaves *S* and *T* at the bottom of the hatchway, and thence up and around similar ones, *V* and *W*, at the top of the run, and then down to the top of the cab, where they are made fast. These sheaves, *V* and *W*, are mounted on a pivoted lever *X*, to the outer end of which an iron weight *V* is attached for the purpose of keeping the cables taut.

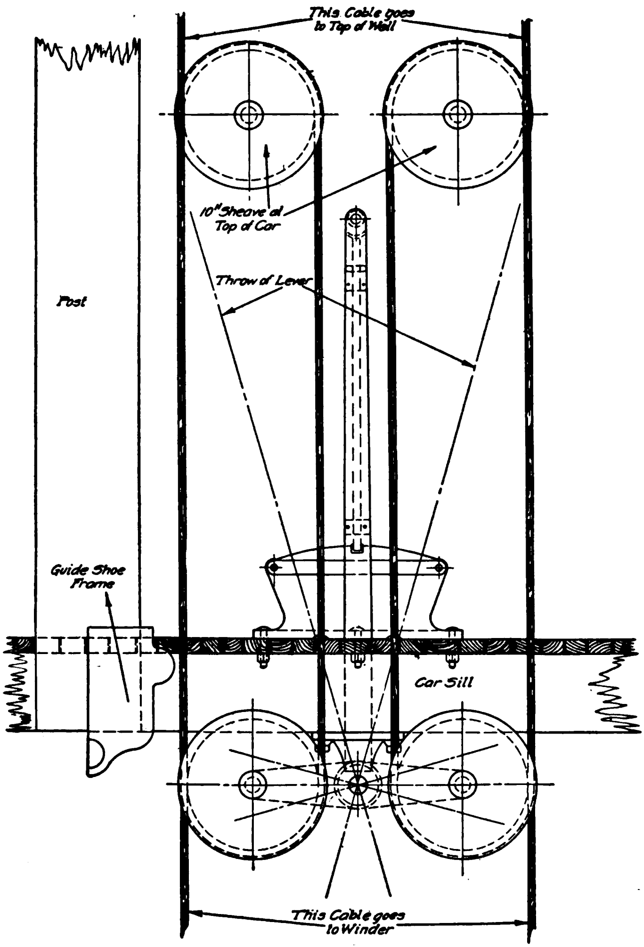


Fig. 94. Operating-Lever Device with Extra Sheaves

When the lever *O* is moved to one side in either direction, and the points *P* and *Q* are respectively raised and lowered, one will take up, and the other give out, a portion of the cable, and the effect will be that the sheaves *S* and *T* at the bottom of the hatchway will be moved

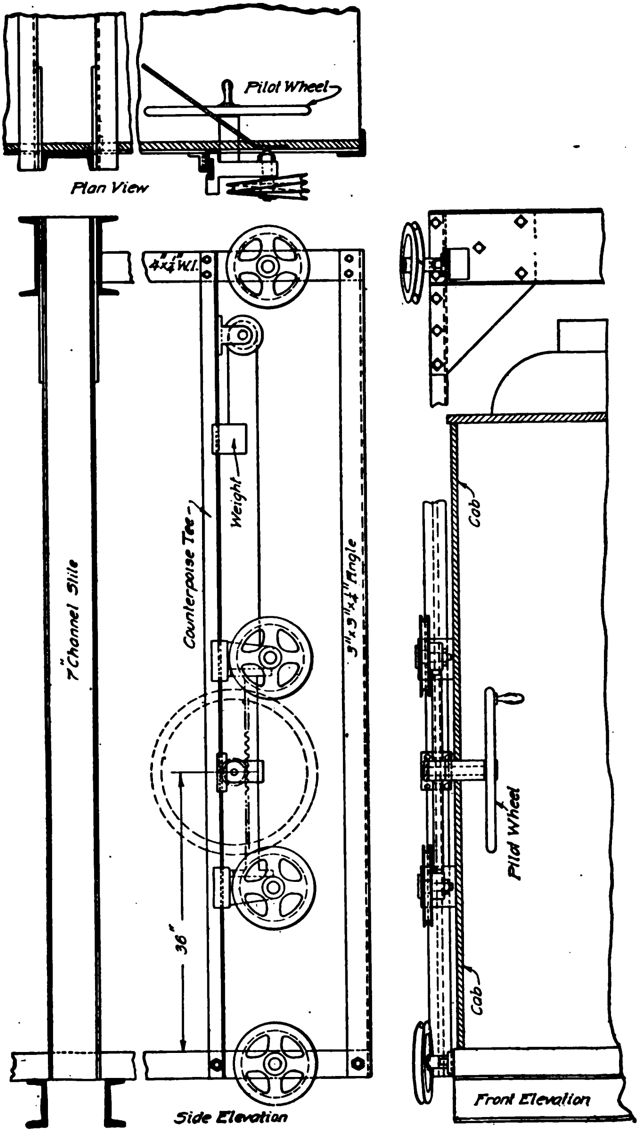


Fig. 95. Pilot-Wheel Operating Device with Rack and Pinion
Courtesy of Kaestner and Hecht Company, Chicago

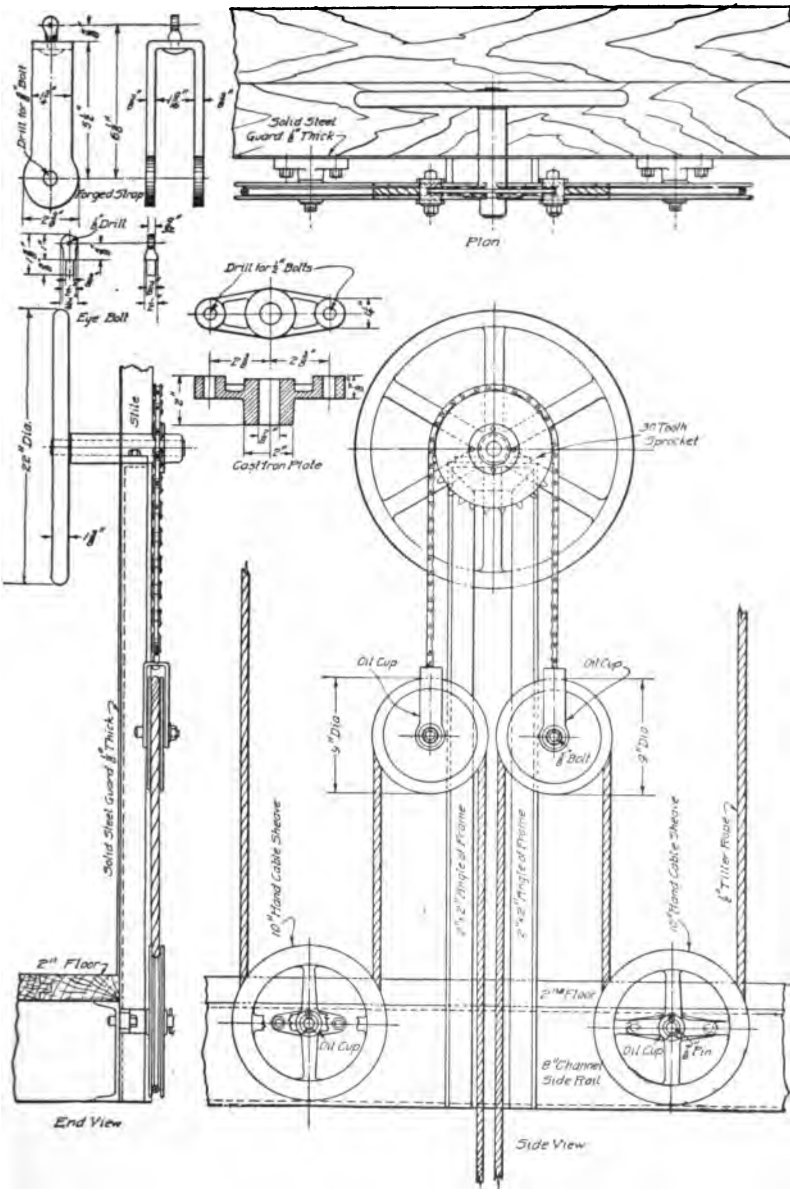


Fig. 96. Pilot-Wheel Operating Device with Chain and Sprocket
Courtesy of Kaestner and Hecht Company, Chicago

one up and the other down. Being mounted on the pivoted lever *Z*, they will carry it with them. This lever will move the lever *E* on the pilot, producing the results previously described.

Other Types. The Crane arrangement was the first practical lever device for the control of elevators. Several others were afterward developed, most, if not all of them, being arranged to operate with fixed or stationary cables in place of cables moving with the car, Fig. 93. One end of each of the cables was attached to the lever at the bottom of the hatchway or led over sheaves directly to the valve apparatus. The other ends were fastened to a suitable beam at the top of hatchway in the penthouse, long eyebolts being used which were threaded their entire length of two feet or more and supplied with nuts for taking up the slack and keeping the cables taut. Figs. 94 to 96 show several other forms most popular at the time. Figs. 95 and 96 show a form of operating device which came into use at this time which is called the pilot wheel. This had the advantage of a greater range of stroke than the lever, so that it was applicable to the ordinary valve with the operating sheave, rack, and pinion. Simply revolving the wheel one-half turn in either direction would cause the elevator to ascend or descend according to the direction desired, while the neutral or stop position was determined by moving the wheel until a certain mark upon its rim was uppermost. This apparatus required more manual effort than the lever and was not, on this account, suitable for high speeds; in certain localities it became, and still is, very popular.

High Speeds with Operating-Lever Device. This method of using the lever in connection with the pilot valve enabled easy starting and gentle stopping to be accomplished at high speeds, and it was only a short time until speeds as high as 600 feet per minute were easily obtained. To reach this speed it was frequently necessary to gear the horizontal machines as high as 10 to 1, the vertical cylinders standing on end in a narrow space alongside the hatchway. There was practically no limit to their length, for the same space would be required for the sheaves, crosshead, and cables. With horizontal cylinders, however, valuable space in the basement of the building was required except where the cylinders were mounted on top of each other. The pressure carried at this time in the compression tanks seldom exceeded 200 pounds to the square inch, and while it was known and admitted that

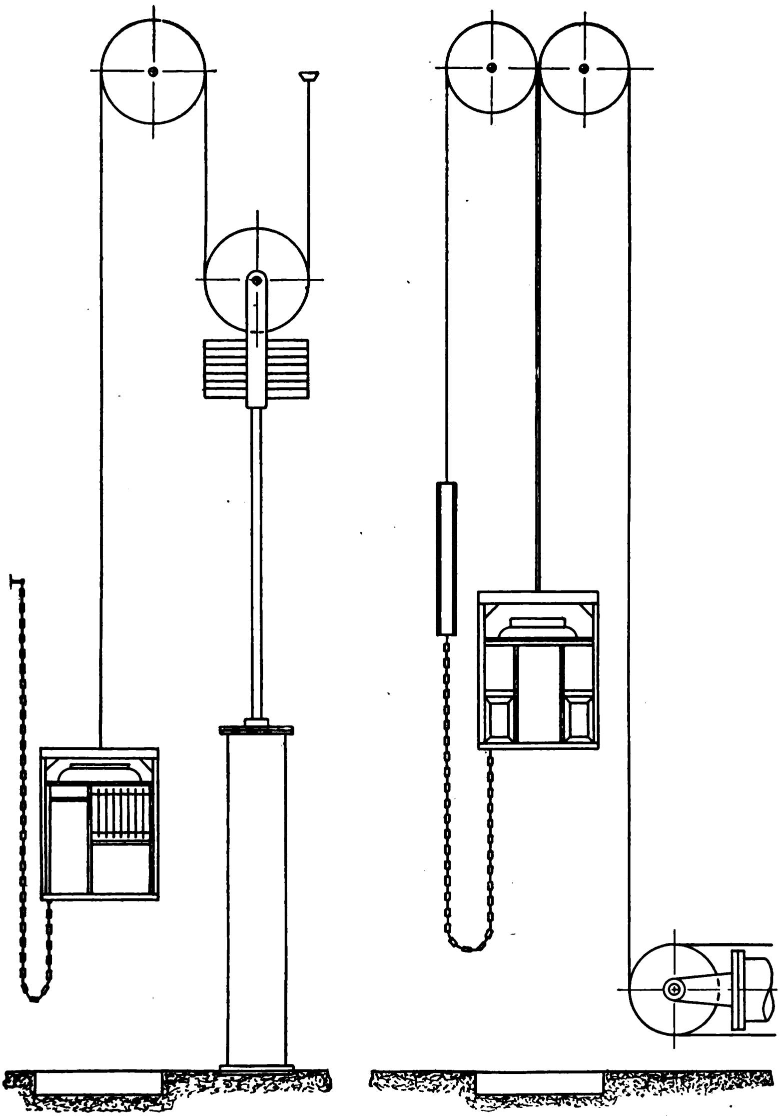


Fig. 97. Diagram Showing Method of Using Counterbalancing Chains

there was a great loss in power caused by friction, due to the use of comparatively large cylinders, no change was made for a long period. The smoothness of operation made the hydraulic elevator seem the acme of perfection. It supplanted the steam elevator in most cases where new plants were contemplated and in many already established.

Counterbalancing Chains. In buildings many stories in height, the length and number of cables used became an important factor in the counterpoising of the cars. When about six $\frac{5}{8}$-inch cables were used on a horizontal hydraulic elevator in a building of 15 or more stories, it was found that if the car was counterpoised even to a slight degree, the weight of the car when at the top floor would not be able to overhaul six cables and move the piston as well, the cables alone weighing something over 800 pounds. Compensating chains were then employed, Fig. 97. A straight-link chain was used which was six or seven feet longer than half the travel of the elevator, and of such a size that it would closely approximate the weight of the overbalancing cables. One end of the chain was attached to a point halfway up the hatchway, the other end being fastened to the bottom of the car platform. When the car was at the bottom landing, the entire weight of the chain was supported from the wall of the shaft. When the car was at the top landing, the entire weight of the chain would hang from the car, thus compensating for the weight of the cables leading down from the overhead sheaves to the machine below. Similarly, for any position of the car between the limits of its run, a proportionate amount of the chain would be hanging from the car, the remainder being carried by the fastening in the wall of the shaft.

In case the amount of weight required for compensation was so great as to make the necessary chain too large, two chains, each of half the weight, could be used. To prevent any noise from the rattling of the links, a piece of soft rope was woven in and out through the links for the entire length of the chain.

HIGH-PRESSURE HYDRAULIC TYPES

Inefficiency of Former Types. Although with a water pressure of from 120 to 200 pounds per square inch, very good speeds and capacities were easily attained, the apparatus required was very ungainly and occupied much valuable space. It was undeniable that a large percentage of the input of power was lost in friction, the principal source of the loss being in the size of the cylinder required and in the cables and high gearing in use.

Efforts had been made to overcome the friction due to the use of many sheaves and cables by using one or more piston rods in a thrust machine. These were of cast iron in the form of toothed racks which geared into pinions on a drum shaft. The element of danger which existed in the risk of a possible breaking of gear teeth made this method of the application of power seem too risky, especially for high runs or for the carrying of passengers, and, although many very successful machines were made and put into operation, they never became very popular.

Elevator builders had for some time felt that if water at a higher pressure was available a great improvement could be effected; but it was not until the introduction of electricity as a motive power for elevators that any effective effort was made in this direction.

Introduction of High Pressures. A manufacturer of elevators in Chicago was determined to investigate the use of high pressures in London, England, and for that purpose sent a commission to London to secure all the information possible on the subject. In London, the high pressure was obtained from high-pressure street mains built and controlled by a corporation, but this scheme had already been unsuccessfully promoted in America. The result of the commissioners' visit was the determination to use water at a pressure of 750 to 800 pounds per square inch, and that its production should be made on the premises in each case. While this arrangement resulted in the saving of considerable space when compared with the previous large horizontal machines, there was still considerable room required for the boilers, pumps, and tanks.

The type of hydraulic engine determined on was the vertical, to be located either alongside or to the rear of the hatchway. As the working pressure was very much greater than that of the low-pressure system, the consequent reduction in the diameter of cylinder required was great enough to permit the pumping engine being located near-by.

Difficulties Experienced. Many difficulties were encountered. Fittings on the feed pipes were hard to keep tight; air leaked out of the pressure tanks; and air at the pressure required was hard to pump. In addition, it was found that the pressure tanks required for the supply of such small cylinders were so proportionally small that there was great fluctuation in the pressure. Accumulators were therefore used. Then it was found that the old cup packings for piston and valves were inadequate. In the case of the pistons, plaited square hemp kept in position by a brass follower ring was introduced as a remedy. With the valves it was found that the passage of water at the high speed, consequent upon the reduced size of openings, wore the holes in the brass linings of the valves so rapidly that it was difficult to maintain a proper graduation. The brass perforated linings were abandoned, and ports or full openings used. This necessitated the use of valve plungers of a different construction.

Still another difficulty was experienced, namely, the operation of the pilot valve under the increased pressure. For while the valve casings, the cylinder, and the pipes and 'fittings had to be materially heavier in order to withstand the increase in the water pressure used, this same cause necessitated a reduced area in the openings feeding both valves and cylinders. In the case of the pilot valves, as a result of this reduction these openings often became clogged or, in fact, entirely closed by small pieces of waste or canvas from the pump piston packings. This occurred so frequently as to become a constant source of annoyance and also to detract seriously from the advantages of the high-pressure system.

Improved Pilot Valve. The difficulty was overcome at last by a Mr. H. F. Witte of the Otis Elevator Company, Chicago. He suggested the use of a separate tank for the operation of the pilot valve, this tank to carry a lower pressure, say 80 to 100 pounds. Upon being tried, it proved to be all that could be desired. It was, in fact, simply a return to the old conditions of low pressure so far as the pilot was concerned. Fig. 98 gives a sectional view of one type of this valve which is in general use.

Construction. It will be observed that the proportions differ noticeably from those of the low-pressure valve, the motor being much larger in comparison with the operating valve. This, it must be remembered, is due to the fact that the pilot and motor are to work on low pressure, while the operating valve is designed for the higher pressure.

A further inspection of Fig. 98 will show that, while the levers for operating the pilot are similar to those used for the low-pressure pilot, the valve, in this case, is differently constructed, in that it is a sort of piston or plunger. Instead of two pipes being connected with the casing of the pilot, there are three. The middle pipe *A* is the

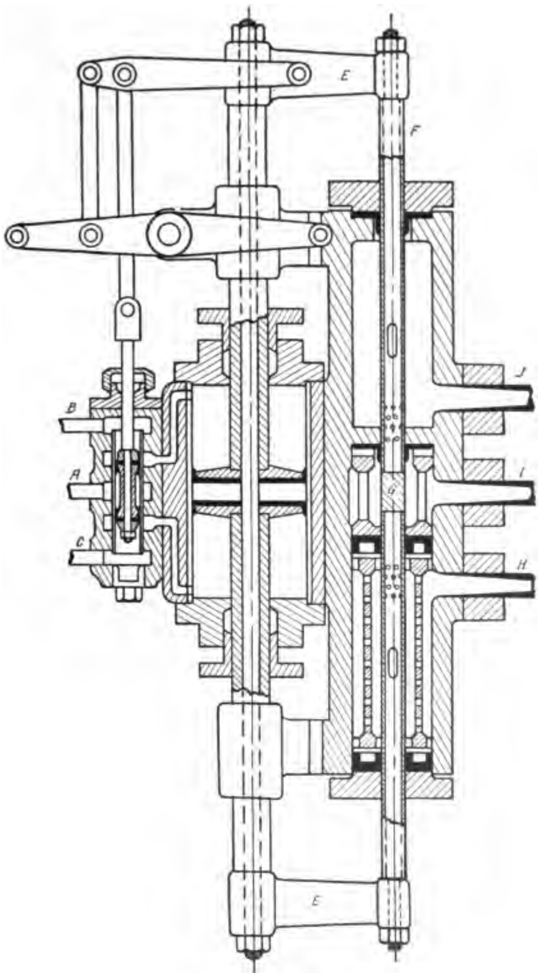


Fig. 98. Section of Witte Improved Pilot Valve

feed, the two outer pipes *B* and *C* being for the discharge from either end of the motor cylinder.

Operation. The motion is exactly the same as in the low pressure. For example, the pilot valve admits water through *A* to the lower end of the pilot cylinder and at the same time allows a discharge from the upper end through *B* and *vice versa*. The levers and their connections are the same as in the other valve, but the pilot is, in this case, attached to one side of the operating valve instead of at its end. The connections with the operating valve are also different, for here both ends of the piston rod of the pilot are connected with

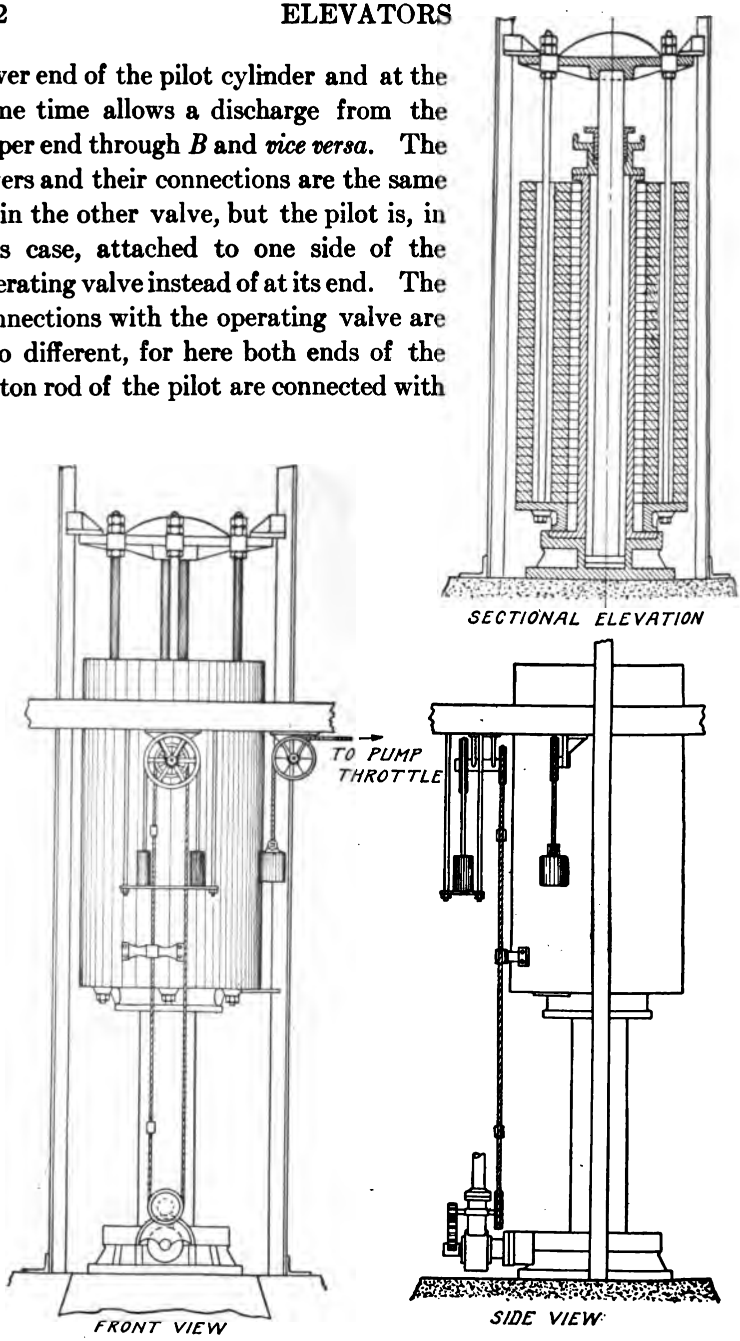


Fig. 99. Details of Accumulator Used to Replace Pressure Tanks

the operating valve by means of the arms *EE*. *F* is really the operating valve itself, being a tube, solid in the center at *G*, with perforations in it for the admission of water to its interior. The port *H*, in the valve casing, is the feed from the accumulator. Port *I* leads to and from the cylinder, while *J* is the discharge.

If, through the action of the pilot, the valve *F* passes upward through the valve casing, the perforations in its lower half are brought into position so as to allow water from the accumulator, Fig. 99, to pass into the port *I* and thence to the cylinder. Should the motion of the pilot be reversed, the operating valve *F* will, when sufficiently depressed, permit the water in the cylinder to escape to the discharge through the port *J*.

A high-pressure installation with a Witte pilot valve, accumulator, and other auxiliary apparatus is given in Fig. 100.

Use of Accumulator. With the introduction of the accumulator, a different method of feeding the operating cylinders of the hydraulic engines was adopted. In using the tanks it had been the custom to make them large enough to hold sufficient water for two or more trips without a very great drop in the pressure, but it was not found feasible to do this with the accumulator, especially where several elevators were in operation on the same system. So the accumulators were made of sufficient capacity for one elevator to run, say, one trip, and for two or more elevators, the increase in capacity was not proportional to the increase in the number of elevators. The idea was to keep the pumps working continuously or nearly so. By so doing, the elevator was really operated by pumping the water directly into the cylinder. Between times, the water discharged by the pump went into the accumulator, which thus acted as an equalizer by supplying water when the pump was slow in delivery, and receiving and storing it up for future use when the elevator was shut down. This arrangement was particularly suitable where a number of elevators were operated on the same system, for the pump was so proportioned that when running at a constant speed it would be just sufficient to supply all the elevators, any differences in demand and supply being taken care of by the accumulator.

Changes Made in Pumps. The operation of the duplex pump, such as was used to supply the low-pressure tank, was found to be

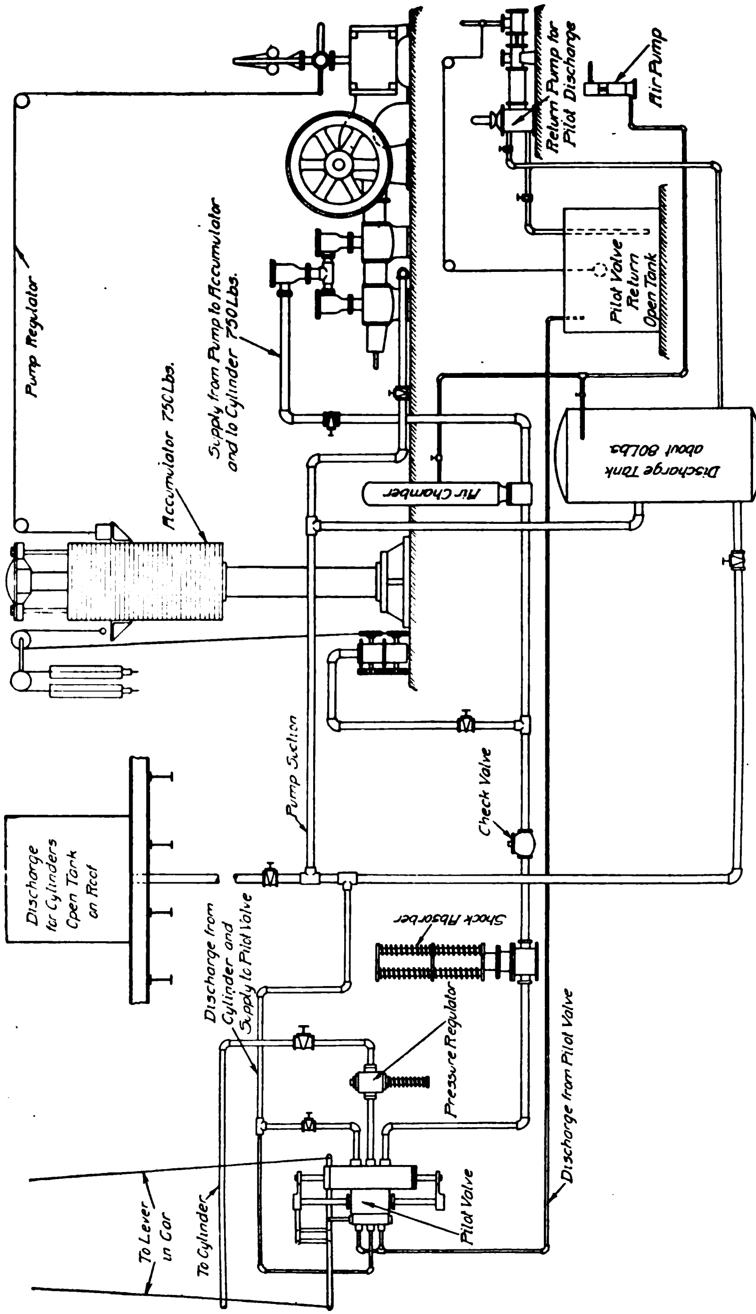


Fig. 100. Diagram of Typical High-Pressure Hydraulic Installation with Accumulator, Roof Tank for Pilot Valve, Shock Absorber, Etc.

unsuitable for this type of equipment because the pulsations of the water pistons could be distinctly felt at the platform, although the pumps were provided with air chambers. The reason for this was that the stroke of the pump was not even throughout, being accelerated at one portion and retarded at another. To remedy this pumps were built to operate with flywheels, thus relieving the apparatus of most of the disagreeable pulsations. (See Fig. 100.)

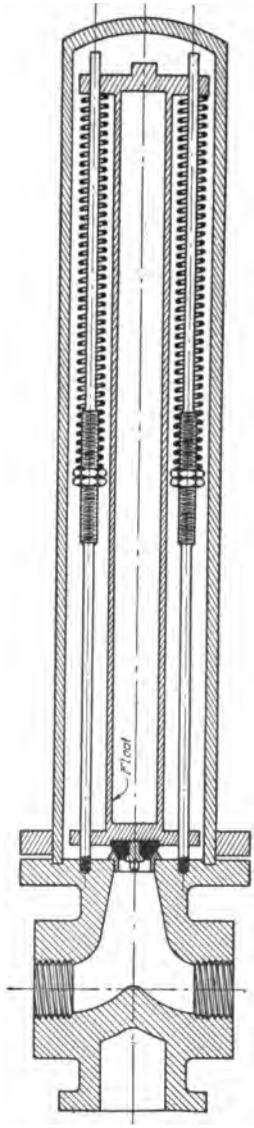


Fig. 101. Air Chamber to Absorb Pulsations of Pump

Introduction of Air Chamber. A special air chamber, Fig. 101, was devised to eliminate what remained of the pulsating effect. It is simply an air chamber made in the usual manner but suitable for high pressure, and having within it a tube closed at both ends and held down on a seat at its lower end by the air pressure in the chamber. Two spiral springs are used to neutralize the weight of the float, thus making the valve more sensitive. These springs can be adjusted to give more or less pressure to the tube, which, when seated, prevents egress of either air or water from the chamber. When properly adjusted, this apparatus will operate to reduce any pulsations in the feed pipe, the inner tube rising and falling with any unevenness of pressure, even though it be but momentary. When at rest on its seat, the inner tube prevents the escape of air into the feed pipe, and thence into the cylinder, where its presence produces an unpleasant jumping of the car.

Shock Absorbers. Water is practically incompressible, that is to say, it has not the elasticity possessed by air, hence if a volume of water traveling through a pipe at a high velocity is suddenly stopped, its momentum and weight, together with its inelasticity, combine to cause it to produce what is called a "water hammer" in the pipes. This is likely to cause a fracture in some of the fittings, and it also tends to displace the packing and damage the valves, being an undesirable feature in either high- or low-pressure systems. In the low-pressure piping it is very well taken care of by the air chamber, but in the high-pressure piping a special arrangement is employed.

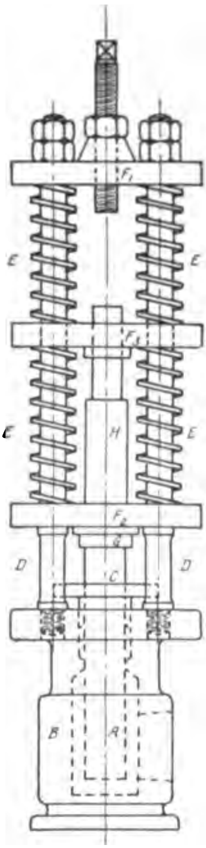


Fig. 102. Details of Shock Absorber

Construction. It will be seen by referring to Fig. 102, that the shock absorber comprises a short plunger or ram *A* of comparatively small area fitted with a casing *B* and a stuffing box *C*. At each side of the stuffing box are pillars or strong studs *D*, two sets of spiral springs *E* and three plates F_1 F_2 and F_3, which are so arranged on the studs as to divide the springs, the upper ones being much heavier than the lower ones. The ram *A* is also made with two shoulders located at *G* and *H* for engaging the plates F_2 and F_3.

Operation. When the column of water traveling at high speed is quickly stopped by the shutting of the operating valve, the momentum of the water is expended on the lower end of the ram *A* and raises it. But the lower shoulder *G* lifts the lower plate F_2, which in turn raises and compresses the lower set of spiral springs. Should they be inadequate to bring the ram to rest, it continues to travel upward until the second shoulder *H* comes in contact with the under side of the second plate F_3, which in turn lifts and compresses the upper and stiffer spiral springs, finally overcoming the momentum of the column of water. When this has been accomplished, the springs return the ram to its first position ready for another and similar operation. The introduction of the shock absorber into a high-pressure system is shown in Fig. 100.

Machine Arrangement. *Cylinder and Plunger.* The piston and comparatively light piston rods in vogue with the low-pressure machine were dispensed with and replaced by a ram or plunger working in a vertical cylinder not bored or finished on the inside. The water was kept from leaking out by means of a stuffing box and of a gland which was bored to fit the outside of the plunger, and which was fitted with hemp packing. The opposite end of the plunger was attached to the crosshead in which the traveling sheaves were mounted. This crosshead or frame was made of steel plates or of channels and fitted with guide shoes running on steel guides attached to the end of the cylinder.

Sheaves. Where a number of sheaves were used for the purpose of getting a high multiple, they were not placed side by side on one shaft, but on separate shafts, one ahead of the other, that is, in tandem. This was done to keep the lateral space occupied by the machine as small as possible. The fixed sheaves were set at the opposite end of the cylinder in a similar manner, and the cylinder was provided with lugs or feet by which it was bolted to the wall of the building or to a frame of structural steel. This in turn was attached to the floor beams or to trimmers of the hatchway.

Counterbalancing Effect. When the water was admitted to the cylinder, the plunger was forced out downward, hence the weight of the plunger, crosshead, and traveling sheaves always acted with the power that lifted the car, and in cases where the latter was small and the load lifted comparatively light, the plunger, sheaves, and crosshead would, in themselves, be sufficient; but in cases where they were not, provision was made for the addition of counterpoise weights attached to the crosshead to make up the deficiency. It must be remembered that only a fractional part of the entire weight of these parts helped to counterpoise the car, for the counterbalancing effect was equal to the total weight divided by the multiple, or number of sheaves on the machine. Thus, if the engine had 6 sheaves, the effective counterpoise of these parts of the engine was only one-sixth of their weight.

REVERSE-PLUNGER TYPES

One of the machines which resulted from the efforts toward improvement it is well to describe, because it really has merit; its lack of popularity in the early form was due to a failure of one of the appliances connected with it rather than to any inherent defect in the machine itself. The inception of this machine, which is known as the reverse-plunger type, was the cause of an important change in the arrangement of the low-pressure tank for the operation of the pilot valve.

Early Type. *Construction.* It will be remembered that the introduction of the low-pressure tank was found necessary for the successful operation of the pilot valve in connection with the high-pressure elevator. This machine had for its object, or rather for one of its objects, the supply of water to this low-pressure tank, thus dispensing with the pump for that purpose. It comprised the usual plunger machine previously described; but its position was reversed and it was made longer, so that its action was really two to one, the stroke of the plunger being half the travel of the car. The plunger emerged from the top end of the cylinder, the fixed ends of the cables being attached near the roof of the building. The sheave in the cross-head ran in the bight or loop of the cables, which passed under and around this sheave and thence up to a sheave at the top of the hatch, and over this down to the car.

Operation. The peculiarity of this machine lay in the fact that the plunger had to enter the cylinder in order to lift the car. Of course, in doing this it was discharging water; therefore it had to lift the car solely by its own weight, the lowering being done by admitting water under pressure to lift the plunger. The plunger was made to discharge the water into the low-pressure tank, and from this tank the high-pressure pump took its supply of water for the high-pressure tank. This feature was a source of economy in power, the added pressure of the supply assisting the high-pressure pump in performing its duties and at the same time dispensing with the low-pressure pump altogether.

Defect. The machine worked admirably, and would have become popular but for an unfortunate accident caused by the giving-out of the air in the low-pressure tank. This caused the plunger to descend quickly, thus rushing the car to the top of the shaft with great velocity. This accident, while it condemned the comparatively new machine, led to the adoption of another arrangement which had some good features.

Improved Type. The improved type dispensed with the low-pressure air tank and substituted in its place an open tank placed high enough to give the desired pressure for operating the pilot valve without the use of air as an auxiliary. This method is now in general use.

DEVELOPMENT OF AUXILIARY APPARATUS

Increased Water Economy. Of course, during this period of experimenting with the high-pressure hydraulic elevator, the minds of those busy with the improvement of the machine had never lost sight of the idea of economizing in the use of water as a motive power.

Use of High- and Low-Pressure Tanks. It occurred to someone that with two tanks, each having a different pressure, some way might be devised whereby either might be used for lifting the load, Fig. 103. To this end a special form of controlling or operating

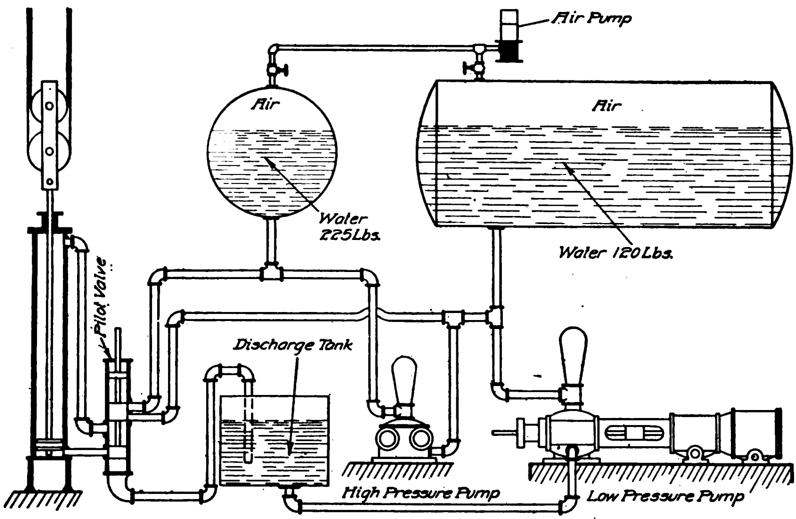


Fig. 103. Typical Installation Using High- and Low-Pressure Tanks

valve was devised by which water from either the high- or the low-pressure tank could be admitted to the cylinder as desired, and it proved quite successful. In this connection a feature heretofore unseen developed, for it was found that when using the water from the high-pressure cylinder even with the heaviest loads a certain amount of the water from the low-pressure cylinder flowed in with it, and this was a source of economy quite unexpected. It will be noticed in the diagram, Fig. 103, that no flywheel is provided for either pump, as shown in Fig. 100, the pulsations of the pumps being absorbed by the elasticity of the air above the water in the tanks.

Improvements in Horizontal Machines. As high-pressure machines were made horizontal, special features had to be introduced.

Ram. To counteract the tendency of the ram to bend inside the cylinder the inner end is fitted with a shoe which rides on the lower side of the cylinder and thus keeps the ram always level. The outer end of the ram is fitted with a crosshead, which carries the traveling sheaves, and which in turn slides upon guides set exactly in line with the cylinder in a manner similar to the guides of a steam engine. The ram does not fit the cylinder for its whole length, but runs through a stuffing box and acts as a piston. Beyond the stuffing box, buffers or bumpers project on each side. These bumpers are exactly in line with bosses on the crosshead, which come in contact with the buffers at the end of the down stroke and prevent the end of the ram from breaking the cylinder head.

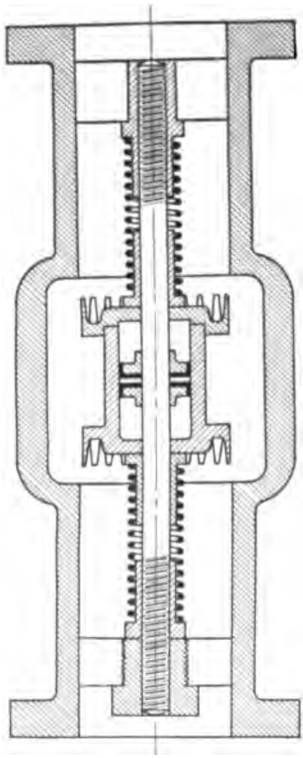


Fig. 104. Section of Speed Regulator

Stop Mechanism. The limit stop valves on this machine are very similar to those used on the horizontal low-pressure engine, except that they are of heavier design and of less area. The stopping mechanism is also similar, being the usual wire rope running over two sheaves, one sheave attached to the valve spindle and the other being an idler simply to carry the rope. Instead of being placed at the extreme end of the machine, the idler pulley is set slightly beyond the middle point of the run or travel of the crosshead. Below the lower part of this rope a long rod is placed, sliding in brackets attached to the frame of the machine. These brackets serve as guides as well as supports for the rod. The end of the rod nearest to the limit valve is fitted with an arm which is made fast to the lower part of the horizontal cable which operates the limit valve. The other part of the rod has the two buttons or stops. The arm which is attached to the crosshead and forms the striker slides on this rod and strikes the buttons at the limit of the stroke at either end. The reason for using this shorter cable is to guard against its coming off the sheave. The operating valve is similar in design to that used with the vertical machine.

Introduction of Speed Regulator. With both these high-pressure, high-speed machines, a type of valve is used which is not found to be necessary with the low-pressure machine, namely, the speed regulator, Fig. 104. It consists of a valve set on a spindle in the feed pipe and adjusted to a central position by means of a spiral spring at either end. That portion of the pipe where the valve is located is enlarged to permit of the free passage of the water around it, depending for its action entirely on the velocity of the water passing through the pipe. Should the speed of flow of the water through the pipe exceed that for which the springs are adjusted, the water will carry the valve along with it, thereby partly obstructing the flow of water, and consequently reducing its velocity. As soon as this occurs the springs gradually restore the valve to its normal position, thus allowing more space for the passage of water. The speed regulator is used to prevent a too sudden starting of the car, and also to restrain its speed, thereby keeping it normal regardless of the improper manipulation of the operating valve by the man in the car.

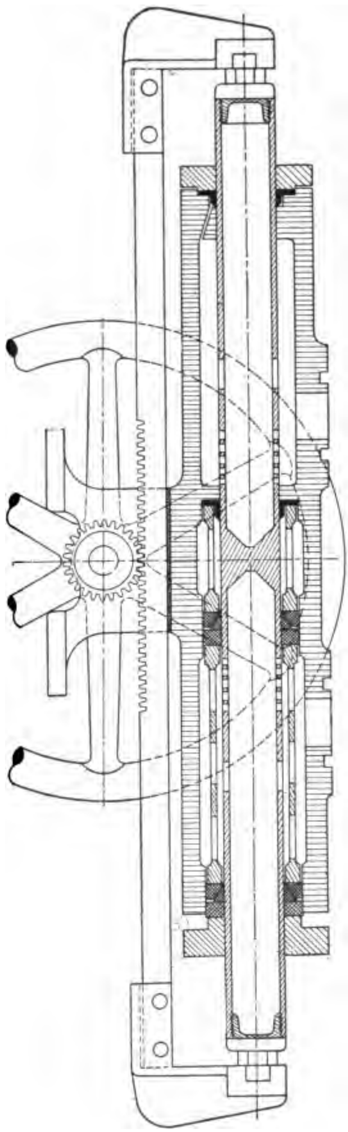


Fig. 105. Section Showing Pilot-Wheel Operation of Control Valve for High Pressure
Courtesy of Kaestner and Hecht Company, Chicago

Development of New Methods of Control. *Pilot-Wheel Operation.* The controlling valve mentioned as being used with the high-pressure hydraulic has been spoken of thus far as being operated by the mechanism of the lever and pilot attachment. In many parts of the country where the pilot wheel is the favorite method of control, a valve has been used which closely resembles in construction the valve heretofore considered, Fig. 105. The only difference lies in the discarding of the pilot attachment and the substitution of a rack and pinion, together with the use of a cable sheave on the pinion shaft. The operating cable is passed around this sheave and made fast thereto. It then passes over suitable sheaves to and up through the hatchway, where it is moved by the pilot-wheel mechanism.

This operating arrangement is found to be very satisfactory, one of the chief advantages being the elimination of all the troubles incident to the use of the pilot—namely, the stopping of the tiny water passages by lint and pieces of canvas fiber from the piston packing of the pumps—and the discarding of the low-pressure tank for its operation. But the majority of those who use elevators do not like the manipulation of the pilot wheel, as most of the wheels require from one-half to three-quarters of a revolution in either direction to produce the up or down motion as desired. This requires a much greater amount of physical labor on the part of the operator and the stops are more difficult to make. The lever, with its comparatively short stroke of less than one foot in either direction, makes an easier control and requires less exertion on the part of the operator.

Electromagnetic Control. This preference for a simple and easy control led some manufacturers to adopt the electric-car switch for this purpose, but although its application has been successfully accomplished the results are not always what could be desired. The pilot valve as heretofore described is used, but, in place of using the cables mechanically operated by the lever, a controlling switch exactly similar to those used with the electrically controlled and operated elevator is placed in the car. An electric cable is led from this switch to a suitable point in the runway, the cable having a sufficiently long loop to permit the free travel of the car throughout the shaft.

From the cable end, permanent wires are run to electromagnets, which are set on the valve proper in such positions that they operate the lever when energized. The current necessary for the operation of this control is obtained either from a lighting current in the building or from a battery. While this method of operation is a success from the electrical point of view, it is not by any means perfect. The chief objection to its use lies in the fact that with this arrangement only one speed in either direction is attainable. Moreover, there is always a liability to derangement through the wetting of the magnets.

Magnetic Control with Push-Button Machine. There is a certain type of elevator with which this form of control has been used extensively, namely, the slow-speed, push-button-controlled hydraulic machine. In some factory buildings, and in localities where electric power is not available for elevator work, but water under pressure is plentiful, elevators of this type have been installed in cases where no attendant was desired and in places where the elevators were used by employes indiscriminately.

The machines have not given entire satisfaction, owing to the fact that it is next to impossible to keep them perfectly tight for any length of time. Should the piston or the packing around the plunger or any of the valve packings leak even slightly, the car will not stand where it is left, but will slowly creep. This will bring about a very awkward condition for, although the car may move only a few inches from the landing, it will derange the electrical connections of the operating device to such an extent that the machine will become inoperative.

For example, it is part of the push-button plan of operation that no door can be opened unless the car is present at that landing; also, that when the car is between two landings, the pushing of the button at any landing will neither start nor stop it. These are safety measures adopted to prevent accidents. When, on account of leakage, one of these elevators travels either up or down from the landing for even a short distance, it cannot be operated from any floor, nor can the door be opened. Hence, in such a case, it is necessary for the operator to go to the basement and there manipulate the valve by hand in order to move the car to the landing. Of course, where the traffic is so continuous that the elevators never stand more than a minute out of use, these conditions do not have time to affect its use.

DIRECT-PLUNGER HYDRAULIC TYPES

The direct-plunger is probably the oldest type of hydraulic elevator, isolated instances of such machines having been known seventy years ago. As its name implies, the plunger is attached directly beneath the platform, which it raises through the medium of water under pressure acting on its lower end, and which it lowers by gravity.

General Construction. The machine employs a cylinder, usually of cast iron, set vertically in the ground, its top end flush with the bottom of the pit, which is usually three feet deep, Fig. 106. Its lower end is closed by means of a cylinder head made up with a water-tight joint. The top section of the cylinder contains the nozzle or inlet pipe and the stuffing box. This top section protrudes above the floor of the pit for convenience of access. The plunger is a hollow tube, now made of steel but formerly of cast iron. Where the height of travel is great the plunger is made in sections connected by means of male and female threads. Some makers make the male and female threads on alternate ends of each section, but the popular way is to make both ends of each section with female threads, a thimble with male threads being used to connect the sections. On the top of the plunger the platform is placed and fastened.

Fig. 106. Typical Plunger Hydraulic Sidewalk Elevator
Courtesy of Warsaw Elevator Company, Warsaw, N. Y.

The operating valve is located either at one side of the hatchway or in the pit. When the latter arrangement is used, the pit must be over three feet deep. The usual guide rails are provided for the platform. When the travel of the car is more than one story, a counterpoise must be added to offset part of the weight of the plunger.

It will be seen from this description that this type of elevator is much simpler than either the horizontal or vertical hydraulic type previously described. However, since the introduction of the high-pressure system, the necessity that has arisen for various adjuncts and appliances has tended to make it quite complicated.

Plunger. For elevators of a low run, say from ten to twenty feet, the machine is very simple. The plunger in all cases is closed at its lower end and the water does not enter it at all, this being essential to its efficiency. For short plungers the lower end is closed by a screw cap, the projecting metal of the cap forming a stop to prevent the plunger from being forced out of the cylinder in case the operating cable should break or the usual limit stop become deranged. Sometimes the plunger bottom is grooved to relieve the pressure in such cases. The pit is usually supplied with bumpers on which the platform settles at the end of the down stroke, thus preventing the lower end of the ram or plunger from knocking out the bottom cylinder head.

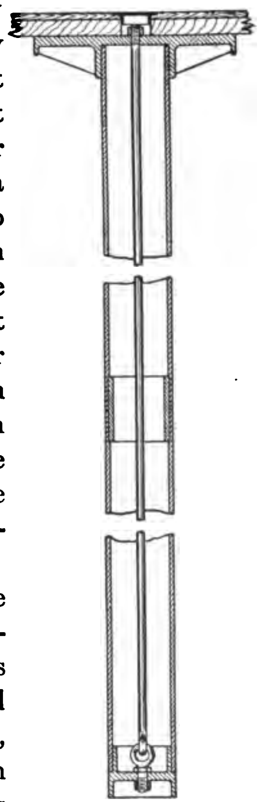


Fig. 107. Method of Fastening Sections of Plunger Together

Cast-Iron Plunger. When plungers were made of cast iron, screw joints were not generally depended upon. Usually the inner sides of the ends of sections were bored smooth and true for a distance of three or four inches, or, in the case of plungers of large diameter, even six inches, and a cast-iron ring or thimble was turned accurately to fit the bore. This thimble was made a little shorter than the combined bore of the two ends of adjacent sections. When the plunger was put together, a thimble was slipped in place inside the ends of the sections coming together, and a hydraulic cement made of a mixture of litharge or red lead and boiled linseed oil was used on the joints. Where ends of the sections came together they were faced true, and through the entire plunger from top to bottom a long wrought-iron rod of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter was passed. Such a rod, Fig. 107, had a thread at each end and, after the top and bottom plates closing the ends of the plunger were in place,

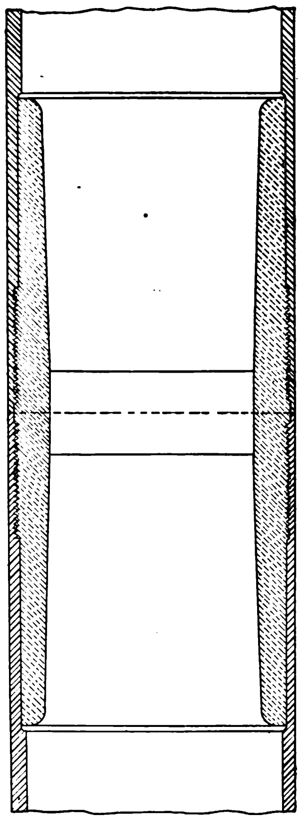


Fig. 108. Typical Joint in Plunger with Steel Tubing

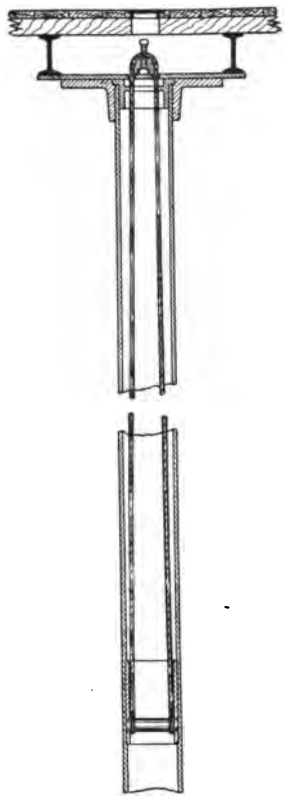


Fig. 109. Cable Method of Reinforcing Plunger Tube

nuts were screwed tight on the ends of the rod, thus binding the whole together.

Steel Plunger. The introduction of steel tubing revolutionized this plan. The inside of the steel tubes was bored and threaded at the ends, the ends of the sections squared as before, and the thimble screwed to fit into the screwed ends of the plunger, as shown in Fig. 108. In putting this plunger together the same hydraulic cement was used as with the cast-iron plunger. The whole was screwed tightly together, dependence for safety being placed on the high tensile strength of the steel of which the plunger was made. This could not be done with cast iron, because its tensile strength is very low and its crystalline nature makes it too brittle for the purpose.

Long Plungers. With the very long, and consequently very heavy, plungers in use at the present time a combination of both these methods is used. The plunger is made in sections, as previously described, with screwed ends and threaded thimbles, but in addition a wire cable is used inside, while a pin is set horizontally across the inside somewhat below the center, Fig. 109. At one end of the pin a wire cable is attached, the cable being led up to the top of the plunger and through the plate at the top and over a half-round block on the plate, thence down again inside the plunger to the other end of the pin, where the other end of the cable is made fast. Through this half-round block is a bolt or bolts, set in such a manner that by turning them the block may be raised and a tension secured on the cable to keep it tight.

By this means the weight of the lower part of the plunger is hanging on the couplings, this being a great relief to the couplings in the upper part of the plunger. Of course these strains on the coupling occur only momentarily as, for example, when the discharge valve is suddenly opened for lowering when the car is at the top of the run and the plunger is almost wholly out of the cylinder. With this arrangement the couplings below the center of the plunger are also subjected to this strain, but only to half the amount the upper coupling would have to carry, if the cable were not present.

Cylinder. The plunger does not touch the inside of the cylinder at all, a space of one inch or more being left all around the cap which closes the end of the plunger. The plunger runs through the stuffing box, and the packing therein keeps the water in the cylinder from escaping. At the upper part of the gland of the stuffing box, Fig. 110, is an annular space for grease, which is supplied from a compression grease cup. Above this is a recess for the reception of a wiper of soft rubber, which is kept in place by a ring attached by bolts to the top of the gland.

Fig. 111 shows with considerable detail the construction of the

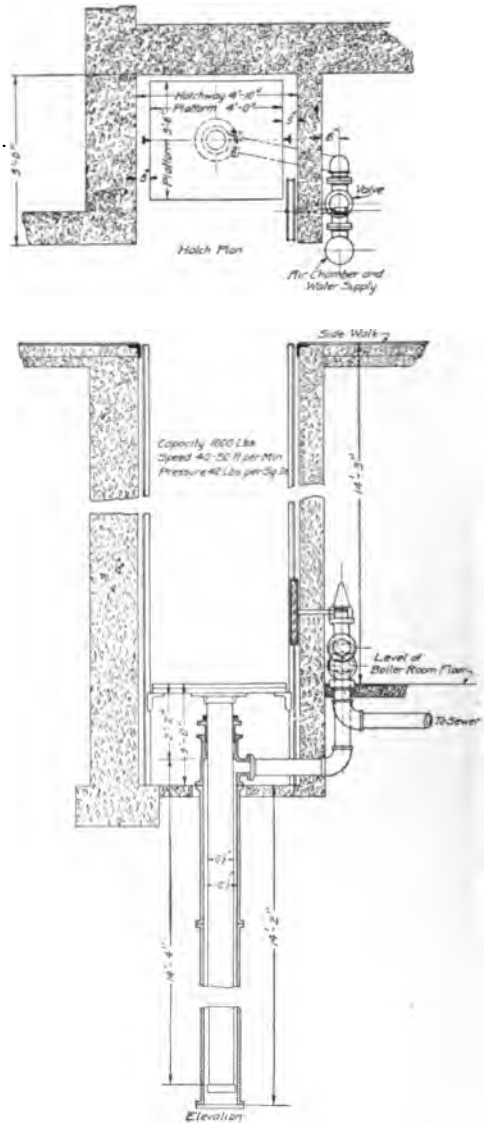


Fig. 110. Section of Plunger Hydraulic Elevator, Showing Details of Construction
Courtesy of Kaestner and Hecht Company, Chicago

cylinder and plunger of a passenger elevator. A hole is drilled into the ground slightly deeper than the total rise of the elevator. This hole is lined with casing until solid rock is encountered, the casing being of heavy steel pipe. Where there is solid rock, steel casing is not needed.

The cylinder consists of heavy steel pipe screwed together with butt joints and welded at the bottom end. The top end is provided

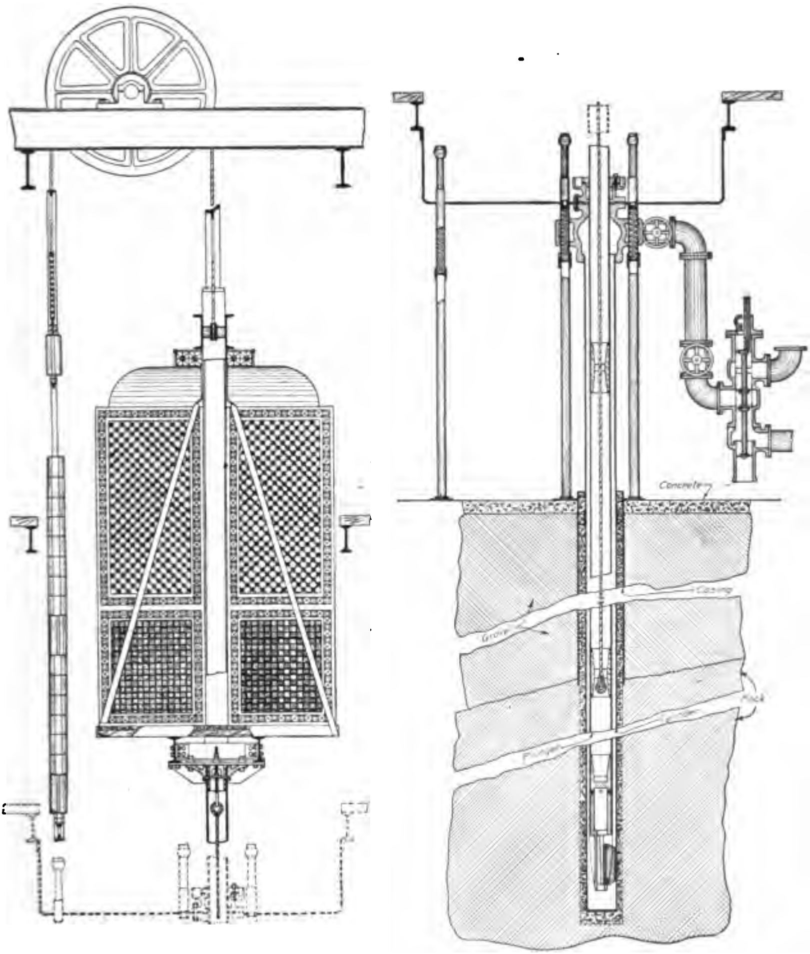


Fig. 111. Details of Cylinder and Plunger of Hydraulic Elevator
Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

with a heavy casting known as the cylinder head, with a stuffing box through which the plunger passes, as previously stated. The cylinder is lowered into the hole and is usually provided with a heavy plate which is used to hold the cylinder in position, the plate resting on the concrete at the top of the hole.

Operating Chain and Ring. In cases where the elevator runs up level with a sidewalk, street, or alley nothing can appear above the sidewalk, and hence the usual striker or stop arm of the platform or car has to be omitted. In its place a chain passing through a hole in the platform and having a ring at either end is used, as shown in Fig. 106. The operating cable, upon which stop buttons are set, runs through the ring at one end of the chain. The stop buttons are so arranged that, as the car approaches either end of its travel, the ring engages with one of them and pulls the cable in the direction to operate the control valve so as to stop the elevator. When the platform is level with the upper landing, the car may be lowered by pulling upward on the ring located on the car platform, thus opening the valve for descending. As the car approaches the lower limit of its travel, the ring passing over the operating cable engages with the lower stop button and shuts off the water.

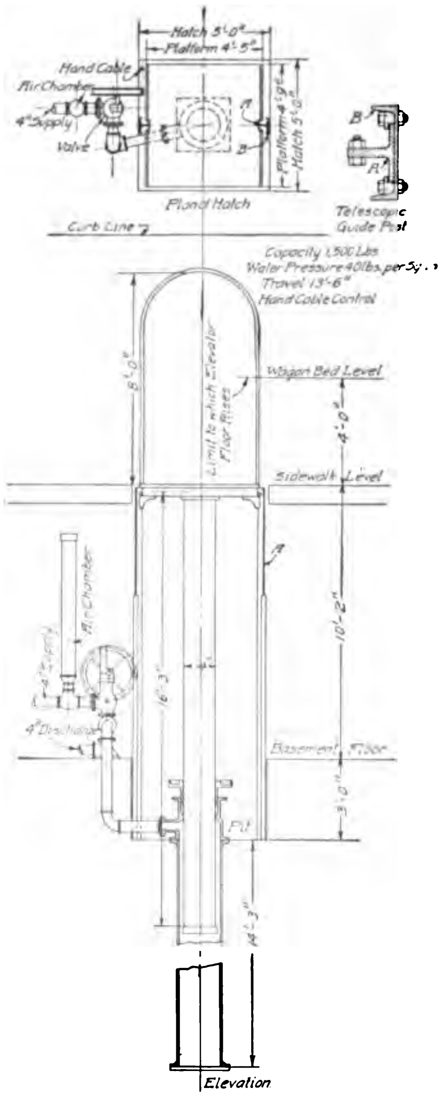


Fig. 112. Sidewalk Lift with Telescopic Guides

Telescopic Guide. Sometimes where an elevator of this description runs up through a sidewalk near the curb, it is found desirable to run the floor above the sidewalk to the level of a wagon bed. In such cases what is called a telescopic guide is used. Fig. 112 shows that this consists of guides sliding within rigidly fastened ones. Upon the arrival of the car at the level of the sidewalk the guide shoe on each side of the car comes in contact with a bolt set in the top of the inner guide and lifts it. This inner guide then slides up in the outer guide as far as the car travels. When the car descends on its return trip, the inner guide descends with the car to its original position, after which the guide shoes continue to travel on the inner guide, the outer guide being used merely as a support for the inner.

Trapdoor Arch. It frequently happens, also, that where the opening at the upper landing is covered by trapdoors, the elevator has to be so made that it will open these doors. In such cases a bow or arch, shown in Fig. 112, is attached to the car, which pushes the doors open as the car ascends. When the car descends the doors close, the arch preventing them from slamming.

Counterpoise Weight. In designing a machine of this type it is essential, therefore, to take into consideration, besides the load to be lifted, the force required to lift the plunger and car, and the inner or telescopic guides, and to open the doors. The area of the plunger must be so proportioned as to enable the machine to perform all these duties with the water pressure available. With elevators of this kind which run inside a building for a distance of from three to twelve stories, the weight of the plunger is a very important factor and the use of a counterpoise becomes imperative.

The plunger being hollow, has, when wholly immersed in the cylinder, a certain amount of buoyancy due to the weight of water it displaces, but as it rises out of the cylinder the buoyant effect gradually decreases.

The loads lifted in elevators of this type in tall buildings where the high-pressure system is in use vary from 2000 to 3000 pounds. Where the working pressure is about 500 pounds to the square inch the area of the plunger needs to be comparatively small and the plunger is made as light as is consistent with strength. Such plungers, as now made, vary in weight from 25 to 35 pounds per foot of length. Hence a 150-foot plunger will weigh somewhere about 4000 pounds. A car of about 6- by 6-foot floor area will weigh approximately 1800 pounds, and will carry enough people to weigh 2600 pounds. The total weight of the plunger, car, and people will be 8400 pounds. At a pressure of 500 pounds per square inch a six-inch plunger will do the work, allowing a good margin of reserve power to meet any emergency; but a plunger of this diameter when fully immersed displaces an amount of water equal in weight to 1800 pounds. Therefore this is the difference in lifting capacity of the plunger between the upper and lower landings. To equalize the lifting capacity as far as possible a counterpoise must be used.

Weight of Counterpoise. If the counterpoise were made as heavy as the plunger and car combined, the car would not descend except when loaded to its full capacity. The counterpoise weight must not approach the weight of the plunger and cab by at least the weight of the water displaced, and a few hundred pounds should be allowed for overcoming friction, etc., in descent; but even with this arrangement, the machine will lift 1800 pounds more at the lower landing than it will at the top. This difference in lifting power at different elevations is compensated for in the following manner.

Effect of Weight Cables. The counterpoise weight is hung by, say, about three times as many cables as would be ample in strength to carry the weight, the additional cables being used to offset as far as possible the difference in lifting power of the machine at various levels. These cables, which are ordinarily of ⅝-inch diameter, weigh about ¾ pound to the lineal foot, or for the six, 4½ pounds per foot. Now, when the car is at the top of the run, all six of these cables would be on the opposite side of the sheave over which they run, or, in other words, they would be hanging in the weight run helping the weight to pull up on the plunger. The combined weight of these six cables, 150 feet in length, would be 675 pounds. When the plunger is at its lowest point, these cables hang down in the hatchway, pulling up on the counterpoise weight with a force of 675 pounds, thus helping the plunger to displace the water in the cylinder. It will be readily seen that the total influence of these cables on the lifting capacity of the plunger would be 1350 pounds, for when the car is at the top of the shaft 675 pounds will be added to the counterpoise weight, while when the car is at the bottom this amount will be subtracted. Hence the difference in lifting capacity between the top and bottom landings is only 450 pounds instead of 1800 pounds.

These figures and dimensions have been given merely to illustrate the point desired, for, in actual practice, such pressure of water for the height and load named would be greater than necessary. With the counterpoise attachment and pressure given, a six-inch plunger would be larger than necessary. A four-inch plunger would be of sufficient area, but a four-inch plunger for such a height would be likely to buckle. A lower working pressure and larger ram would therefore be more practical.

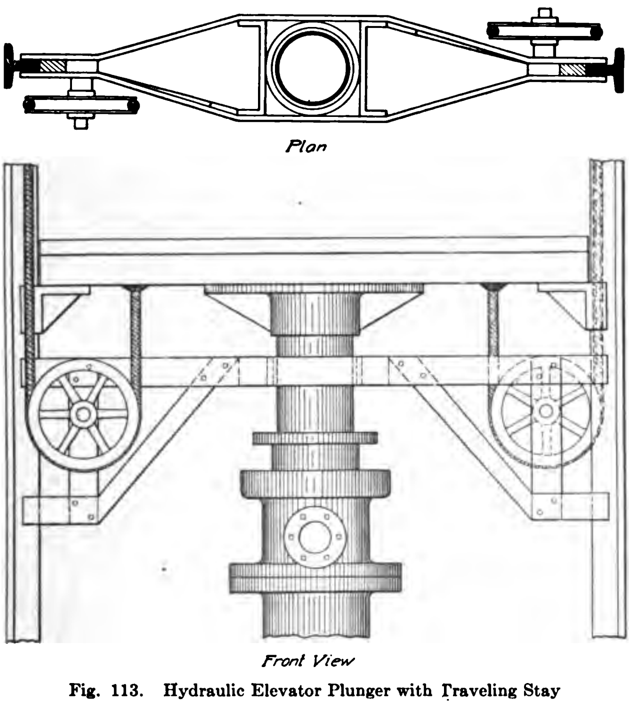


Fig. 113. Hydraulic Elevator Plunger with Traveling Stay

Traveling Stay. Even when the plunger is well proportioned, there is a tendency for it to buckle under heavy loads and great heights. To prevent this an ingenious device, shown in Fig. 113 and known as a traveling stay, is used. A ring is bored to fit the plunger loosely, and is fastened to a frame which extends on each side to the guides on which the car travels. To the ends of this frame are fitted two guide shoes to travel on the guides, and two sheaves, one on each side and revolving on pins attached to the arms. Two ½-inch cables, one on each side, are led from a point a little more than halfway up the run, down the hatchway, and under each sheave, thence up to the bottom of the platform, where they are made fast.

With this arrangement, the car on ascending will carry this yoke or frame up with it, but, due to the sheaves, the frame will travel only half as far and half as fast as the car does. Hence, when the car has reached the top of its run the yoke will be halfway up the shaft, or at the point where the plunger would be inclined to bend out of a straight line. Hence if there is a tendency to bend, the frame will prevent it. When the car descends, the frame will also descend of its own weight.

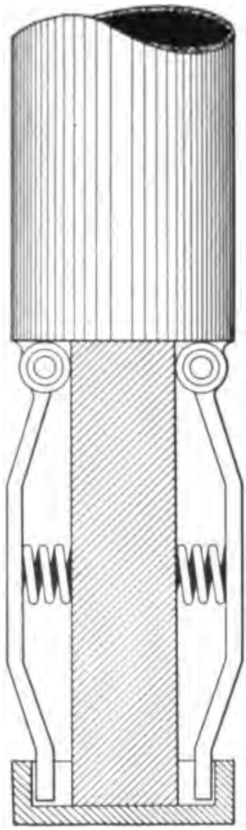


Fig. 114. Spring Type of Plunger Stay

Plunger Stays. In the case of a plunger for a run of one hundred feet or more, the pressure of the water against its lower end, when the car is at the bottom level, has the same tendency to buckle it as when the car is at the top of the run, for it must be remembered the cylinder is not bored smooth and the plunger is supported only at the stuffing box.

Plunger Shoes. The lower end of the plunger is often fitted with three or four shoes, Figs. 114 and 115, which rub on the sides of the cylinder. These shoes are made rather long and their ends rounded so that they will freely pass any minor inequalities or roughness on the inside of the cylinder. To further assist in their movement they are fitted with springs to aid them in overcoming obstacles.

Plunger Brushes. Instead of bronze shoes some prefer to use stiff brushes with bristles of hard-brass spring wire set in a soft metal back, which is set in a groove in the bottom end of the plunger. Three or four of these brushes are used, equally divided in space around the plunger, but in such cases the spring used in the other type to force the shoe out against the sides of the cylinder is omitted and the soft metal back, which is usually babbitt, is held rigidly in place. The spring-wire bristles are longer than is necessary to reach the sides of the cylinder, and hence act as springs until they are worn too short to be of further service, when new brushes must be put in. Both devices work well, but the shoes are probably the more substantial.

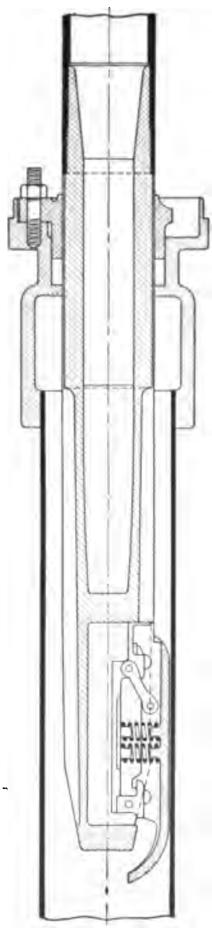


Fig. 115. Shoe Type of Plunger Stay

Limit Devices. *Limit Valve.* With such an arrangement as here described, it has been found necessary to use limit stop or automatic stop valves, as shown in Figs. 116 and 117. These are somewhat similar to those described as being in use with the horizontal and vertical hydraulic machines, but the mechanism of this machine will not admit of a similar arrangement for their operation. In this case two limit valves are used, one for each end of the run. Both are situated in the pit near the operating valve and close to the top of the cylinder. To operate them, two cables are used, one for each valve. These are ½-inch tiller cables and extend from top to bottom of the run. The upper ends of these cables are fastened permanently at the ceiling or to the beams carrying the counterpoise sheaves.

Both limit valves are arranged with their operating sheaves at the same side of the hatchway, and the cable for the lower limit valve is led down the opposite side of the hatchway to that on which these sheaves are located, and thence diagonally across beneath the car to the valve sheave. A sheave is then attached to the bottom of the platform in which the cable will run, the latter being kept taut so that it will remain in the groove of the sheave. When the car approaches the lower landing, it carries the cable out of straight line, thus putting a strain upon it which causes the cable to unreel from the valve sheave and operate the valve.

The cable attached to the sheave of the upper limit valve is run up the hatchway on the same side the sheave is located, but at the top it is attached at the opposite side alongside the other cable. A sheave is attached to the top of the car to run on this cable, and when the car approaches the upper landing, a similar movement of the upper limit valve is produced in a like manner. Each valve is supplied with a lever and weight to bring it back to its "open" position upon the return of the car. This description of the arrangement of the limit stop valve is somewhat general, but all limit valves work on approximately the same principle.

Hollow-Plunger Device. Some makers, besides using the limit valves on the high runs, use another device to prevent the possibility

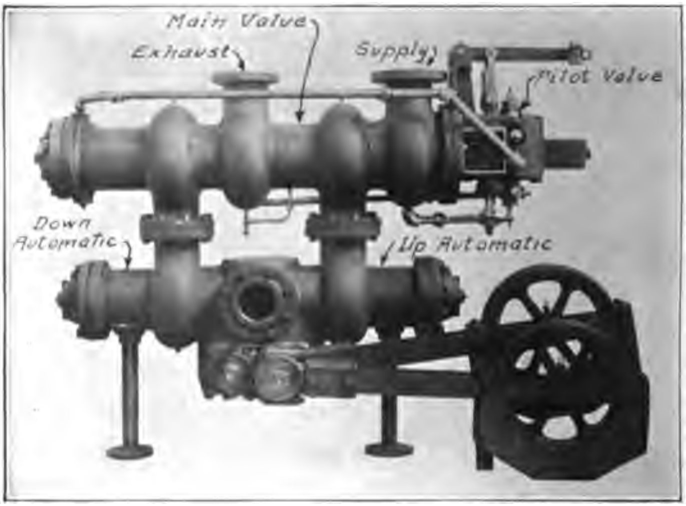


Fig. 116. Side View of Limit Stop Valve for Direct-Plunger Type
Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

of running the platform so high as to jam the car up against the overhead beams, should the limit stop valves fail. This scheme is to attach to the lower end of the plunger, by means of a strong bolt, another section of plunger which is hollow. It is attached below the closed end of the plunger, and carries the shoes or brushes for centering. This section is made of brass, so that it will not corrode and thus become so thick with rust that, when required to act, it will pass the stuffing box.

This section being hollow and open at its lower end, the water has free access to all parts of it, and near its upper end, where it joins the plunger proper, there are three or four holes through its sides

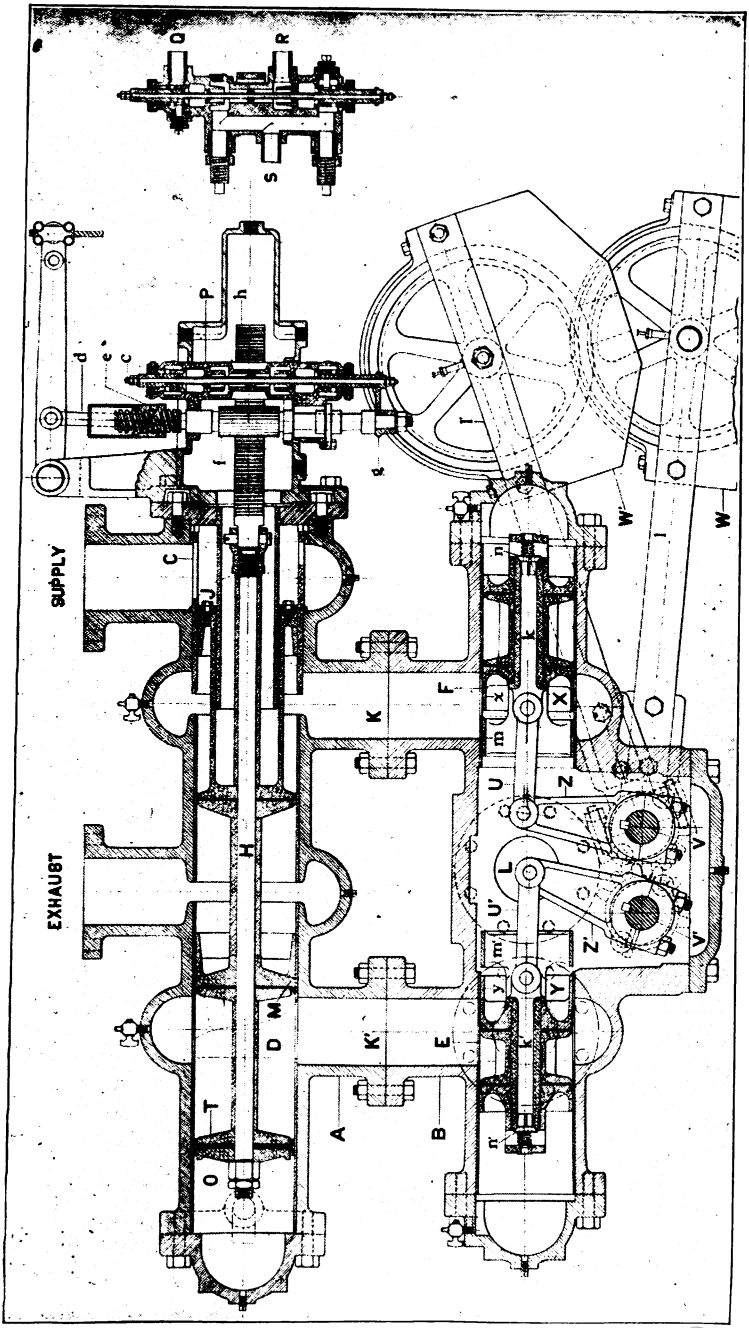


Fig. 117. Sectional Details of Valve Shown in Fig. 116
Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

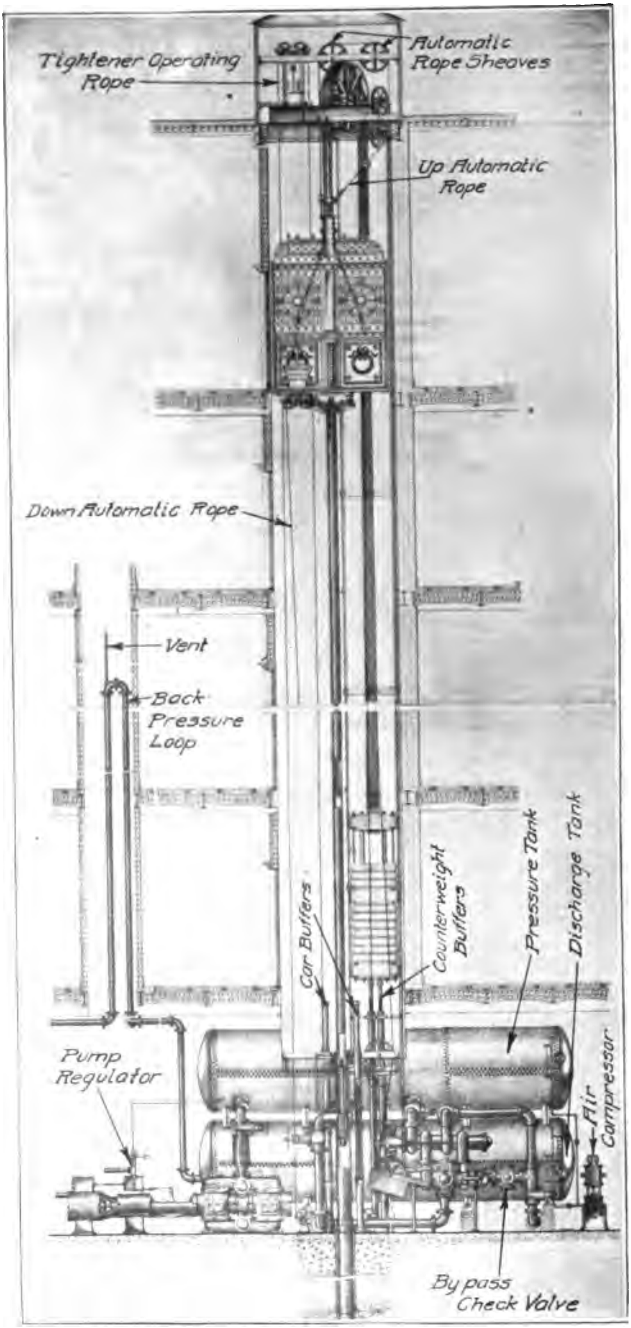


Fig. 118. Vertical Section of Typical Back-Pressure Loop Elevator Installation

Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

which are equal in area to the feed pipe. Should the limit stop valve fail to work and the plunger continue in its upstroke until the platform should rise, say 18 inches above the top landing, this lower brass section of the plunger would then pass on up through the packing in the stuffing box until its holes would be above the gland. Then, of course, any further water fed to the cylinder would escape through these holes into the basement; but this is a lesser evil than jamming the car into the upper beams. When this device is used, both the cylinder and plunger are made longer than for the ordinary arrangement.

Operating Valve. In some minor details the construction of the operating valve is slightly different from the valve used with the hydraulic elevators before described, but in the essential points it is similar, the slight differences being due largely to the individual ideas of the various makers. The means of operation is identical with that of the other types, namely, by hand cable, lever pilot wheel, and pilot valve, according to the pressure, speed, distance traveled, and the service for which the elevator is designed. Many of these elevators are operated by the push-button control previously described, and the same objections exist with this type of machine as with the others.

Back-Pressure System. Fig. 118 shows a complete back-pressure loop elevator installation. The objects of the back pressure are to assist the pump, to act as a water counterbalance for the descending car, and to prevent space forming underneath the plunger. Two closed tanks are shown in the figure. The upper tank is the pressure tank containing water under high pressure; the lower tank is the discharge tank, and is charged with low pressure. The high pressure is caused by compressed air generated by the air pump. The low pressure is caused by the back pressure in the loop or vertical water column. This amounts to 2.3 pounds per square inch per foot of rise.

In the case of a plunger elevator ascending at high speed, if the valve should close too suddenly, the plunger might leave the water and a disagreeable jar would be the result as the plunger dropped back. To prevent such condition a by-pass is provided from the low-pressure discharge tank to the elevator cylinder, a check valve being in the line, and in the event of the plunger leaving the water the check valve is opened, allowing the water from the low-pressure tank to fill in any space that might occur as above described.

At the top of the back-pressure loop is a vent to prevent the water siphoning. The lower end of this pipe is connected to the sewer, and, in the event of the discharge tank becoming overcharged, the water would simply flow from the loop and into the sewer.

Operation. The cycle of operation of the tank system as shown in the illustration is as follows: The pressure tank contains about $\frac{2}{3}$ water and $\frac{1}{3}$ compressed air. When the valve is opened to raise the elevator, the compressed air forces the water through the valve to the elevator cylinder, causing the elevator to rise. When the valve is shut off, the elevator rests upon a column of water in the cylinder. When the valve is opened to lower the car, the car descends by gravity, forcing the water out of the cylinder into the low-pressure tank.

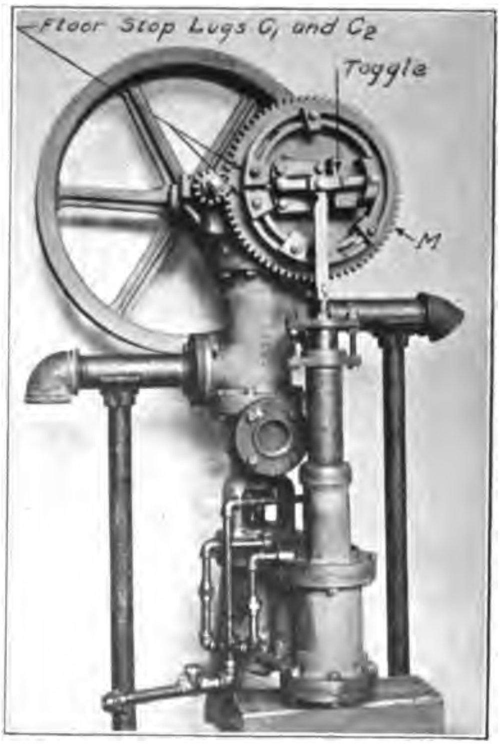


Fig. 119. Pilot Valve Designed to be Electrically Controlled from Car
Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

The steam pump shown in the illustration is provided with a regulator governed by compressed air. When the pressure reaches the maximum point, the steam throttle is closed automatically and, likewise, opens as the pressure falls. Therefore, the pump automatically takes the water from the discharge tank and forces it into the pressure tank as fast as it is exhausted from the elevator cylinder. The air compressor is used only occasionally to make up for any slight loss caused by leakage.

Electric Control. An automatic valve designed to be electrically controlled from the car is shown in Fig. 119, and the general arrangement of the valve and controller is shown in Fig. 120. The valve is governed in its opening movement by electrically operated pilot valves and is closed by the movement of the car itself, thus insuring absolutely accurate stops.

The valve is of the regular three-way balanced rack-and-pinion type, except that a motor cylinder is used at the lower end for opening the valve and another motor cylinder is used to operate a clutch to stop the car. The valve is closed by means of a running rope, which is attached to the car and connected to the valve drum as previously described. As the car moves the drum revolves, a clutching device being used to center the valve.

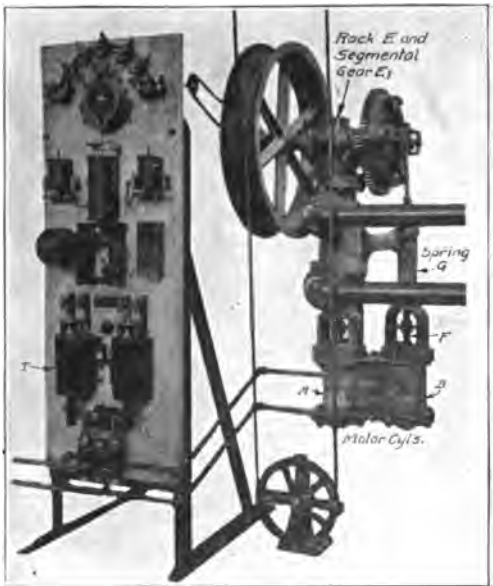


Fig. 120. Arrangement of Valve and Electrical Control
Courtesy of Standard Plunger Elevator Company, Worcester, Massachusetts

The rack E, Fig. 120, at upper end of valve stem engages a segmental gear E_1, which is direct-connected to a clutching arrangement. When the elevator is started, the rack E is moved up or down, as the case may be, by motor cylinder A, and the clutching arrangement is set in an angular position and must be returned to a horizontal position when the valve closes. The clutch is opened by pressure in the motor cylinder B and closed by the coil spring G. When the pilot valve is opened to run the car up, water is admitted to the motor cylinder, forcing the piston F down and uncovering the port to the motor cylinder, A. The water passing into motor cylinder A forces the piston down and opens the main valve.

The pressure in motor cylinder B overcomes the spring G and releases a clutch bar which is between the two floor-stop lugs C_1 and C_2, there being two lugs for each floor, See Fig. 119. The clutch bar is moved back by means of the toggle connections, and the piston in motor cylinder A, when moving, shifts the clutch in an angular position by means of the rack E and segment gear E_1. When the elevator is running at full speed, the pressure holds the two pistons in the motor cylinder down or up, as the case may be, and when this pressure is released by the pilot valve closing, the spring G instantly returns the piston F to a central position, and the clutch bar engages the slot between the floor-stop lugs, similar to C_1 and C_2. The continued movement of the drum, which is driven by the rope connection to the moving car, revolves the clutch back to a horizontal position, incidentally centering the main valve stem, which is connected through the rack and segment gear. It should be noted that the gear M has two floor-stop lugs for each floor, and, as the gear revolves, the lugs representing the floors pass the clutch in regular order until the clutch acts.

The pilot valve which governs the main valve is unbalanced to insure positive seating and is solenoid-controlled, as shown at T in Fig. 120. A dashpot cushion is provided at the lower end of stem to prevent the unbalanced valve jarring when seating. The stem simply drops into a pocket of water, which slightly retards the quick-moving stem.

HEAVY PASSENGER ELEVATOR ENGINE WITH FULL ELECTRICAL CONTROL
Courtesy of Warner Elevator Manufacturing Company, Cincinnati, Ohio

ELEVATORS

PART III

ELECTRIC ELEVATORS

Early Types. The first application of electricity as a motive power for elevator service was made in the year 1889, and was doubtless suggested by its successful use on street cars and in driving lines of shafting in industrial establishments. The installation consisted of an ordinary shunt-wound motor belted to a countershaft, which in turn drove a two-belted worm-geared hoisting apparatus. The starting, stopping, and reversing movements of the cage, or platform, were obtained theough the medium of an operating cable by means of which the open or cross belt was shifted as desired from the loose pulley to the driving pulley of the hoisting machine or *vice versa;* a brake was applied automatically with the cable at stopping position.

In this type of machine, the motor had to be started and allowed to attain normal speed before the elevator could be put into service and, furthermore, the motor had to run continuously even when the elevator was being loaded or unloaded. This arrangement was very wasteful of electric current and the speed was limited.

Various attempts were made to overcome these difficulties, and in many cases the methods used were unique and proved impractical. One of these, the Pratt-Sprague, consisted of a long screw running horizontally in bearings at either end, which were driven directly by a motor placed at one end. The screw ran in a nut having a cross head, which traveled horizontally on guides, the same as the cross head of a horizontal hydraulic elevator, and was supplied with sheaves on either end. The construction of the machine was such that a double set of traveling sheaves and also fixed sheaves were necessary. The cables were rove over these sheaves like any horizontal hydraulic, and the motor was reversible.

One of the principal features of this type of machine was the construction of the nut which traveled on this large screw. It was supplied with steel balls on the "pull" side of the screw, and these ran close together in single file through a channel, which carried them around through the threads of the nut and caused them to return to the other end of the same after they had passed through. Of course, there had to be so many of them that they completely filled the channel from one end to the other, and it was thought that their use would reduce the friction to a minimum. It was found, however, in practice that flat spots were soon worn on them and they ceased revolving, thus cutting grooves or scores in the thread of the screw—a very serious matter. Elevators of this type were also very prone to become deranged, and their operation was not as economical as had been anticipated.

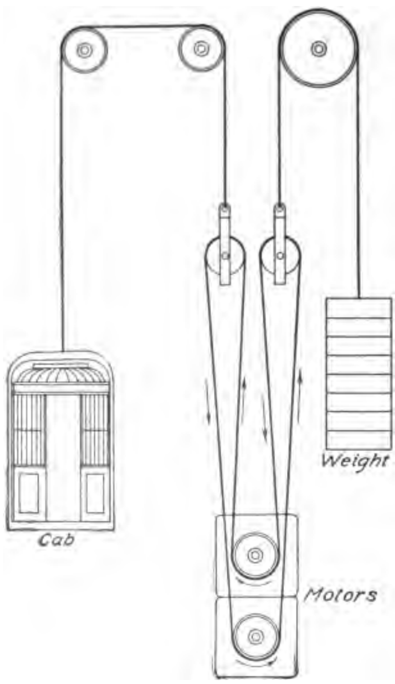


Fig. 121. Diagram of Fraser Elevator Driving Mechanism

The controlling device was quite novel and the operation of the cage very agreeable and pleasant. The control of the motor driving this screw was effected by means of a small pilot motor, which in turn was operated by means of push buttons in the cage. Very few, if any, of these elevators are in use at the present time.

Another type was the Fraser elevator, the driving mechanism of which consisted of two motors set one above the other. These motors were necessarily of the slow speed type, running about 420 r.p.m., and each one had upon the armature shaft sheaves of about 20 inches diameter. Cables were arranged so as to form a double bight or loop around each of these pulleys on the armature shafts, as in Fig. 121. The cables ran from these sheaves over two pulleys, one attached to the car cable, and the other to the counterpoise cable. The motors ran in opposite directions, and by means of rheostats placed in the cab the fields were weakened or strengthened, in order to vary the speeds of the motors. Referring to the diagram it may be seen that when both motors were running at the same speed, no motion of the car would result; but by varying the speed of either motor, the car would run at a speed equal to half the difference in speed of the two motors. No motor reversing apparatus was needed, the motion of the car being obtained entirely by the change in speed; this gave a most desirable method of making stops and starts. The machine was very severe on the cables, so destructive in fact that they had to be frequently renewed; and taking it altogether, the design was not found so desirable as had been anticipated, from the standpoint either of economy or maintenance. However, actual results in operation were all that could be desired, including the speed attained and smoothness of stops and starts.

Difficulties with Variable Speeds. In the latter part of 1889, the first attempt was made to run elevators by means of the motor attached directly to the worm shaft. Two elevators built on this principle were installed in buildings on Broadway, New York City, but they were not eminently successful, owing to their inability to start under a full load and to difficulties experienced with the controllers.

It was soon discovered that a motor which was entirely shunt-wound did not have sufficient torque to start the load unless a motor enormously large for the work was used, thus entailing an additional expense which did not seem warranted. A trial of a series winding in addition to the regular shunt winding was found to solve the problem satisfactorily as far as starting was concerned, but the use of the compound motor caused the elevator to have a variable speed depending upon the load iifted. This speed variation interfered seriously with the stopping of the cage exactly at the different landings, even when the stops were made automatic by means of a striker attached to the cage, an arrangement which was quite popular and in general use at that time.

To remedy this defect the controller was so constructed as to cut out the series winding as soon as the motor had attained its normal speed, leaving it to run on the shunt winding only. This arrangement produced the desired results, viz, a normal and regular car speed under all loads and consequently perfect control in stopping the car at the various landings. The details of the method by which this has been accomplished will be fully described under the heading "Control".

These difficulties overcome, the electric elevator became a real competitor of the older and better known hydraulic types.

MOTOR DESIGN

Requirements. The motor requirements for elevator service differ materially from those for almost any other kind of work and the duties performed are, with possibly one or two exceptions, the most exacting.

In most lines of work the motor is started running light, and the load is applied after the normal speed has been attained. The elevator motor, however, must not only be able to start under full load, but it must pick up, or attain, its proper speed under that load and do it within a period of from four to eight seconds. After normal speed has been acquired, the speed must remain unchanged until the circuit is broken for the purpose of stopping.

Fig. 122. Direct-Current Elevator Motor
Courtesy of Warner Elevator Manufacturing Company

Direct-Current Motors Most Suitable. To any one conversant with the subject, it will be apparent that a special design is absolutely essential for this particular service. With an alternating-current motor, only an approximate fulfillment of the requirements is possible; but with a direct-current motor, the degree of perfection is indeed gratifying when compared with the service obtained only a few years ago. Some of the special features of the direct-current motor designed for this work are as follows: low speed; high starting torque; massive frame, Fig. 122, and field cores; ample shunt windings fully up to the full power of the motor; series windings equal to at least 50 per cent of the horsepower of the motor, these to be in sections so they may be cut out gradually as the motor picks up speed, and to consist of wire almost, if not quite, as large in carrying capacity as the service wires; brushes of sufficient carrying capacity and with an ample area of commutator contact; and rigid brush holders that will not jump or clatter when the motor is running.

High Cost Inevitable. A motor built on the lines just suggested and operated by a well-designed controller will give very satisfactory service and will last for years if kept properly cleaned and lubricated. This last condition is seldom met, for, generally speaking, elevator motors do not receive the attention they should have. Furthermore, the motors are not always of a design suitable for the work expected of them, and it has taken an enormous amount of urging, of argument, and of pleading on the part of the elevator maker to get the motor builder to recognize the peculiar needs of this kind of service. The motor manufacturer is not altogether to blame for this, for frequently the keen competition met with in securing desirable contracts has tempted the elevator builder to use an inferior motor—a practice which has invariably led to trouble. All attempts to produce a less expensive motor which would at the same time give the proper service have failed. Today the features enumerated above are fully recognized by all the best and most reliable motor makers as being absolutely essential to a serviceable and long lived motor for this kind of work.

Faults in Design. *Light Shafts.* One of the mistakes which designers often make is the result of early practice in connection with belted transmission. In these early forms, where the pulley of the motor was much smaller than the driven pulley and the motor started before the load was applied, the low starting torque allowed of a much lighter armature shaft than would be necessary when the motor started under full load. As a result of the change to direct-connected design and to the practice of picking up under load, many instances of shafts twisting off under the heavy starting torque bear witness as to imperfect design or to an attempt to skimp material.

Heating of Motors. Again, motor designers in many cases reasoned that because a motor in this kind of service ran intermittently, it did not have time to heat to a dangerous extent before it was stopped, and during the interval before starting again it would cool. With this fallacious deduction as a basis, they built every part of the machine of light weight for the sake of economy in production, with the result that the motor was heated to a very unsafe degree in its efforts to start under load and the insulation around the copper wires comprising the windings of both armature and field was ultimately destroyed. The rewinding of these coils is an expensive operation and, of course, the loss of efficiency of the motor during the transition from perfect insulation to an actual short circuit in the coils is a more insidious and baffling process.

This brief description clearly explains the absolute necessity of having motors ample in power and of proper design, with liberal windings, field cores, and frame. Another practice which resulted in bad heating was that of keeping the field windings of the bipolar motors excited all of the time in order to produce a fairly prompt start. This resulted frequently in incipient fires and even where this did not occur it brought about the premature destruction of the field windings. Today, in all cities where regulations are in force to insure proper installation of electric elevator equipments, the current must be entirely cut off from the motor when the elevator is stopped, a regulation which has proved as beneficial to the elevator maker as to the owner of the plant. Furthermore, bipolar motors have been entirely discarded for this service by the best makers as they have been found less efficient than other types, especially in starting under load.

Slow Speed. It used to be contended that a slow speed motor was not so efficient as those of higher speed, but as the question of design has been more thoroughly investigated and understood, these objections have all been overcome. In fact, such a degree of perfection in the design of motors for elevator service has been attained that within the last few years motors running efficiently at a speed as low as 40 r. p. m. are frequently met with in connection with the so-called gearless type of elevator engine.

MODERN TYPES

Interpole Motors. For variable speed elevators a type called the "Interpolar Motor" is now in general use. This motor, as its name would indicate, is a direct-current motor with additional poles and field windings interposed between the regular fields, making it an 8-pole motor, Fig. 123. The interpoles are provided with series windings, the wire used being as large in cross section as the line

Fig. 123. Interpole Motor Field Ring and Coil
Courtesy of Electro-Dynamic Company

which feeds the motor and consisting of one continuous wire, one end of which is connected with the line and the other end with one of the armature leads. Current flowing in these windings energizes the interpoles, thus making them alternately north and south poles, or the reverse, according to the direction of the current passing through them.

The regular fields of the motor are wound both series and shunt, as shown on page 165. When the motor is started, the current flows through these heavy series windings and gives the motor abnormally heavy fields at the slow speed, thus enabling it to start under as heavy a load as it will be called upon to carry at full speed. The weakening of these abnormally heavy fields by decreasing the current in the interpole windings and cutting out the series windings on the regular fields increases the speed of the motor to double its starting speed. This, of course, is done through the agency of the controller in one, two, or three steps, thus giving the motor two or three speeds as may be desired. These speeds are about 375 r. p. m. to start with, and 950 r. p. m. for full speed.

In high speed elevators running at 350 to 400 f. p. m. at maximum, this is a valuable feature in a motor because it enables the operator to start and pick up speed gradually, the acceleration occurring during a period of time covering only a few seconds.

Fig. 124. Alternating-Current Type of Elevator Motor
Courtesy of Warner Elevator Manufacturing Company

These results may be obtained either through the medium of the operating switch or by an automatically operating device attached to the controller.

Alternating-Current Motors. With motors built to run on alternating current, Fig. 124, none of the features described are obtainable, the motor being simply started and allowed to attain its normal speed if the elevator is unloaded, or its nearest approximate when loaded. The variation between the synchronal and full load speeds is from 5 to 10 per cent, the alternating-current motor resembling to some extent the compound-wound direct-current motor in this respect. The greatest difficulty experienced with motors of the alternating-current type is their lack of ability to start under a heavy load, and for this reason proportionately larger sizes must be used, the increase in horsepower required being fully 33 per cent. This increased size of the motor is really an advantage, for, besides giving a heavier torque at starting, it furnishes an excess of power which enables the motor to run at full speed without such noticeable fluctuations with changes in load as would be the case with a smaller motor.

CONTROL

Functions of Control. Starting, accelerating, slowing down, stopping, and holding the elevator securely at the various landings are governed by the *control*, which is, therefore, a very important part of the operating mechanism of the electric elevator.

Starting. In starting, the brake is released and simultaneously the current is admitted to the motor. With direct-current motors, however, the full strength of the current may not be admitted until the motor has attained nearly its full speed. The current is controlled by passing it through resistance coils or through cast-iron grids made from iron of a known degree of purity and density. These coils or grids, which are arranged in sections, or *banks* as they are technically termed, are introduced into the circuit when the current is first admitted to the motor and by their resistance tend to cut the current down to a limit that is safe for momentary admission to the motor windings without endangering the insulation.

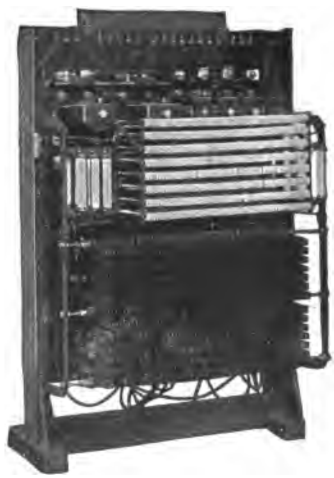


Fig. 125. Back View of Control Board
Courtesy of Otis Elevator Company

Acceleration. The moment the armature starts to revolve, the strength of the current flowing through it may be slightly increased without danger. As the strength of the current increases so does the speed of the armature, and with each increase of speed other sections of resistance are successively cut out of the circuit until the armature has attained nearly its normal speed. At this time the current is allowed to pass directly from the line into the armature, thus giving it the acceleration necessary for its full power and normal speed.

TYPES OF CONTROLLERS

Functions. A controller differs from the ordinary motor starter in that it performs several other functions besides that of simply starting the motor. It controls the energizing or cutting out of the circuit the solenoid which operates the brake; it reverses the direction of rotation of the armature as desired; it controls the resistance in the field circuit, thus giving increased speed when needed; in the case of the interpolar motor previously described, it cuts in or out the series windings for the purpose of controlling the power of the motor to start up under load; finally, by introducing resistance into the armature circuit, a dynamic brake power is generated for use in slowing down the elevator and when lowering very heavy loads.

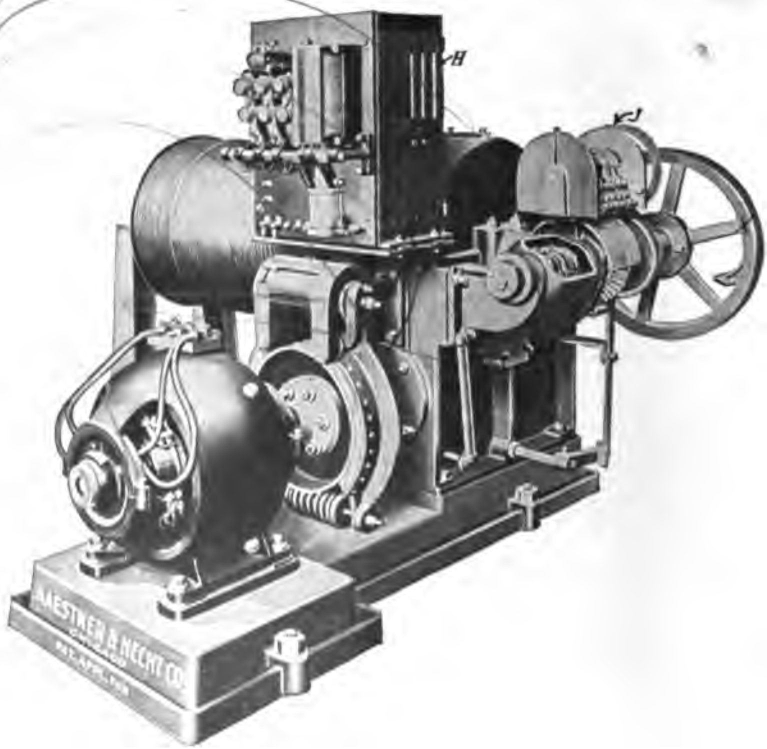


Fig. 126. Freight and Passenger Elevator for Direct Current Operated by Lever or Hand Cable
Courtesy of Kaestner and Hecht Company

The controller as usually arranged consists of banks of resistance mounted on one side of a marble or slate slab, Fig. 125, on the opposite side of which are arranged the various solenoids and switches by means of which the different operations above described are carried out. This slate or marble slab is held upright by a suitable iron frame and holes are drilled for the passage of various wires and for the bolts used in attaching the parts to the slab. Marble makes the

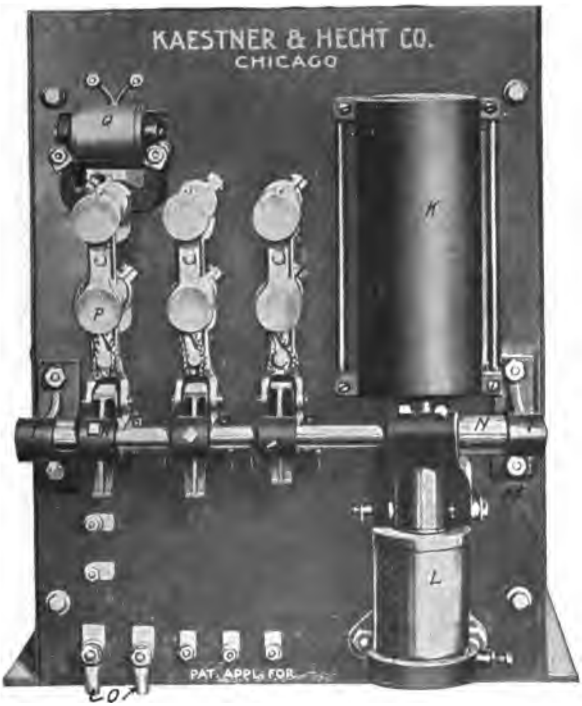


Fig. 127. Direct-Current Semi-Magnet Controller for Hand Cable and Lever Control Operation
Courtesy of Kaestner and Hecht Company

best switchboard material on account of its perfect insulating qualities, although slate is equally as good if free from streaks of metal, the presence of which will prove fatal to perfect insulation.

Direct-Current Controller. *Controller Proper.* A good example of the more simple direct-current type of controller is shown at *H* in Fig. 126, and in Fig. 127, which gives a front view on a larger scale, with the various solenoids and switches mounted in position. Referring to Fig. 127, *K* is the main solenoid, the energizing of which causes the plunger to rise and pull up the lever *M*, causing the shaft *N* to make a partial revolution; the cams *R* which are attached to the shaft *N* are, by its rotation, made to close the switches *P* consecutively (the cams being adjusted in proper position to do this), and, as each switch closes, it cuts out one bank of resistance and thus accelerates the car. The amount of time for accomplishing this is regulated by the dashpot *L*, a short tube filled with oil, containing a

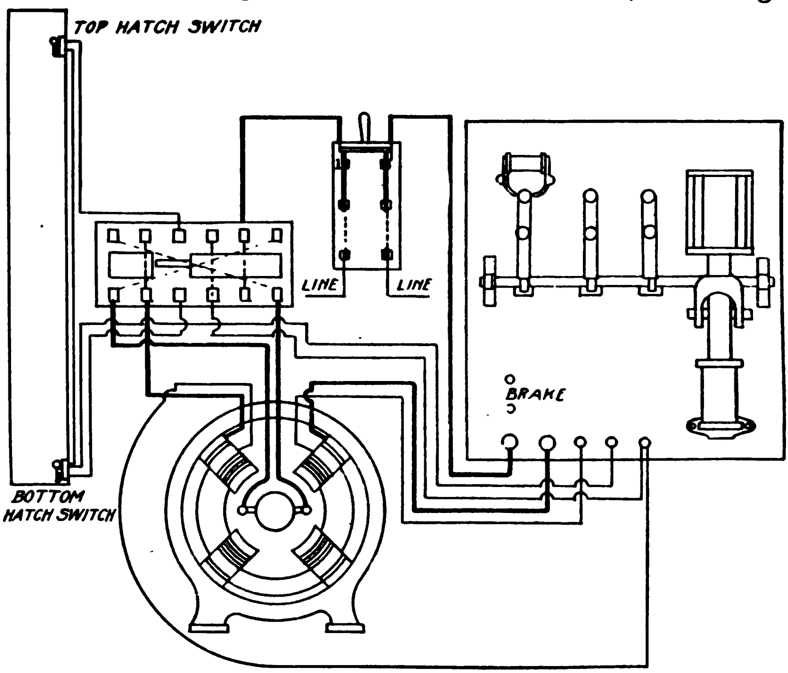


Fig. 128. Wiring Diagram for Semi-Automatic Controller for Compound-Wound Dynamo
Courtesy of Kaestner and Hecht Company

piston attached to the lower end of the solenoid plunger. By allowing the oil above the piston to escape through a graduated opening to the lower end of the cylinder, the upward motion of the plunger is retarded at will. The time required to close the three switches is from four to six seconds, depending on the nature of the work being performed by the engine. The moment the circuit is broken or opened for stopping, the plunger is quickly restored to its original position by means of a quick-opening valve working in one direction which allows the oil to return to its place above the piston. *Q* is a magnet, the office of which is to blow out the arc caused by opening the last switch.

In order that the student may get a better idea of the circuits necessary to allow the controller to perform its functions, a few typical wiring diagrams will be introduced. Fig. 128 is a diagram of a semi-automatic controller for a compound-wound motor.

Starting and Stopping Switch. The opening and closing of the circuit for starting and stopping the motor are accomplished by means of the starting switch *J*, Fig. 126. This switch, which is of the rotating make-and-break type, is connected to the operating sheave by means of a pair of spur gears, and when the switch is made to revolve by means of the operating cable (which is passed around and attached to it), this closes the circuit in the direction it is desired that the elevator shall run. This controller performs but two functions: (1) cutting out the resistance in order to increase the current and bring about the proper speed; and (2) releasing the brake by energizing the solenoid *I*, Fig. 126, which pulls together the upper ends of the brake shoes, neutralizing the effect of the powerful spring connecting their lower ends, Fig. 129. Hence, the brake is applied at all times except when the solenoid *I* is energized. The wisdom of this arrangement is seen in case of accident or failure of the electric current, for the brake is then automatically set.

Fig. 129. Brake Shoe Operated by Solenoid

Alternating-Current Controller. *Mechanically-Operated Type.* When an alternating current is used for operating the elevator, different types of motor and controller are necessary. Only two- and three-phase motors have been found applicable to this problem, as no successful reversing alternating-current motor of the single-phase type has yet been made. As to the controller, the use of the solenoid on alternating-current circuits is not in general favor owing to the expense of production and its noisiness in operation. In these cases, therefore, the makers have resorted to mechanical means for operating the brake and switches on the controller, while the cheaper and slower types are operated by hand cable or lever device at the car.

An electric engine of this type, Fig. 130, corresponds in every respect to that shown in Fig. 126, except that the brake *1* and controller *2*, also shown in Fig. 131, are mechanically operated and the motor is of the alternating-current type.

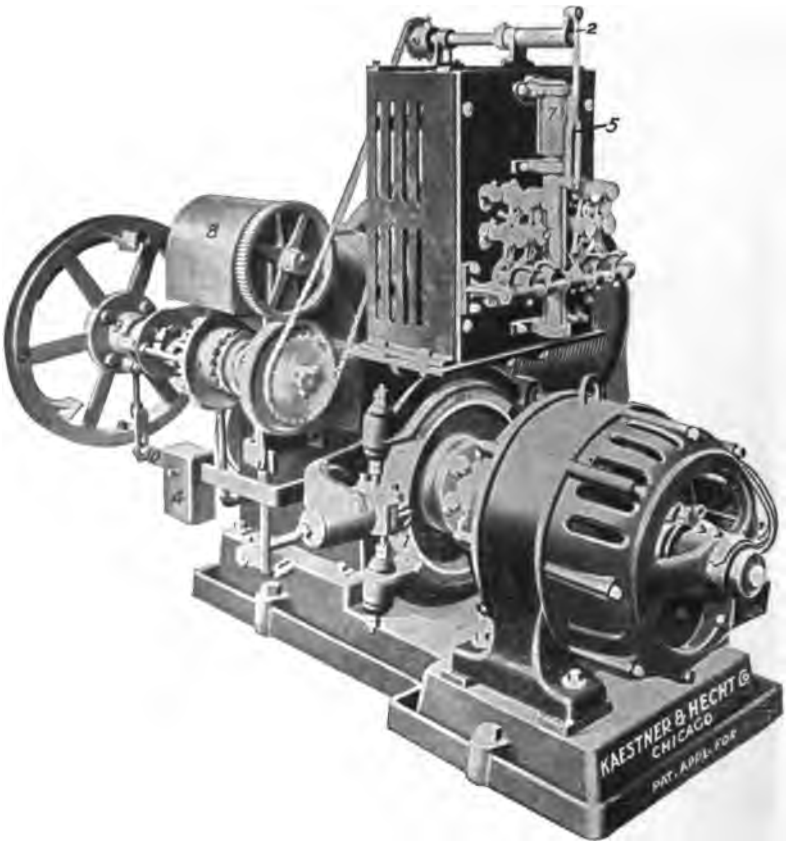


Fig. 130. Freight and Passenger Machine for Alternating Current
Courtesy of Kaestner and Hecht Company

To operate the controller, one-quarter revolution of the operating sheave *3* causes the crank *2* to make one-half revolution, the ratio between the sprocket wheel on the end of operating shaft and that on shaft at top of controller being two to one. When the crank

2 makes one-half revolution in either direction, the pitman *5* goes with it, leaving the plunger *6* free to descend by gravity. The motion of this plunger is retarded by the action of the dashpot *7*, in precisely the same manner as that for Fig. 127. The action of this plunger in dropping is practically the same as in the electrically-operated type, causing a shaft to revolve partially and, through the medium of cams, to close switches and thus cut out resistance from the motor. The making, breaking, and reversing of the circuit is done by the switch *8*. When the operating sheave is revolved in either direction to start the elevator, a cam at *9* lifts the brake lever *10*, thus

Fig. 131. Alternating-Current Mechanical Controller

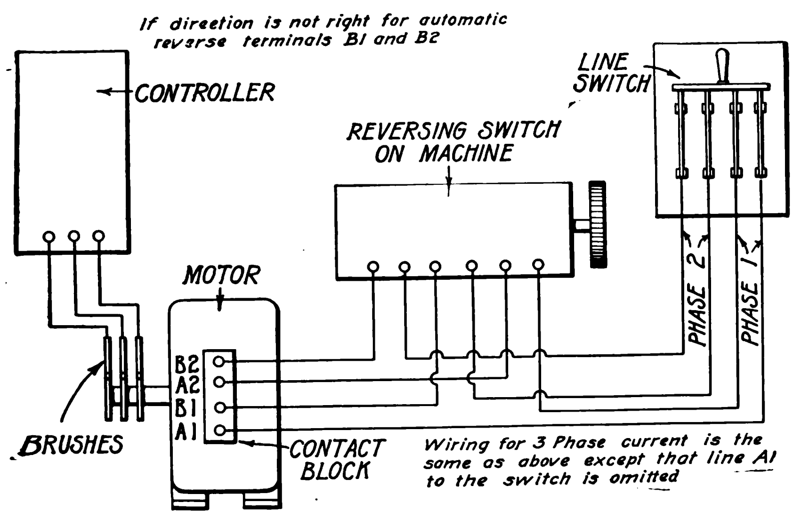


Fig. 132. Wiring Diagram for Two-Phase or Three-Phase Elevator Equipment with Mechanical Control

releasing the brake; and when the operating sheave *3* is returned to its original position, it drops the brake lever, and the weight *4* applies the brake by gravity.

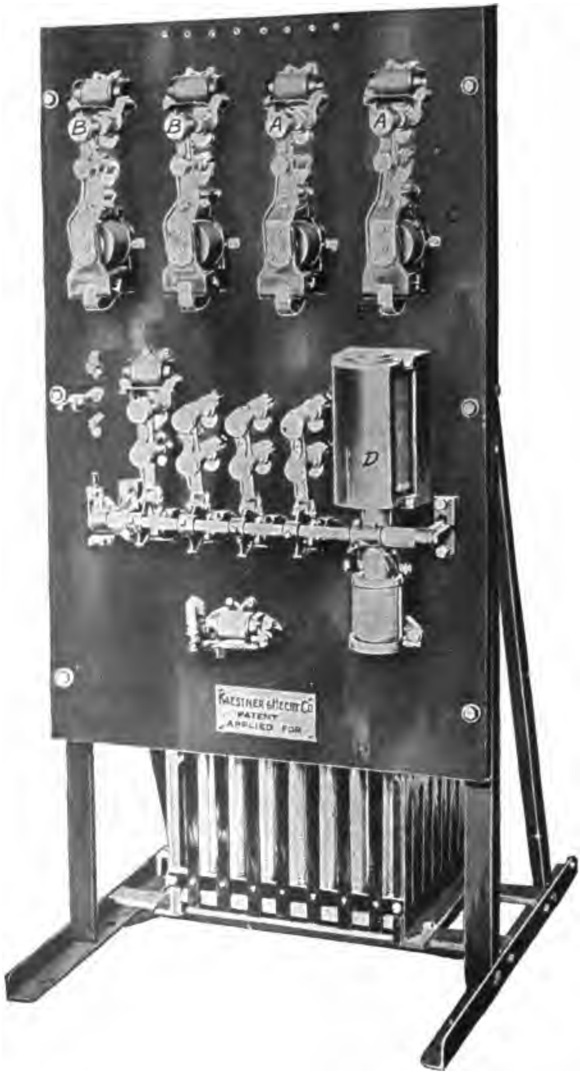


Fig. 133. Single-Speed Full Magnet Controller
Courtesy of Kaestner and Hecht Company

The wiring diagram, Fig. 132, shows the circuits for a two- or three-phase motor with mechanical control.

Magnet Control. When the motion of the car is governed by electrical means, the switches on the controller which open and close the circuit to the motor, are operated by means of electromagnets; hence the term "full magnet control". Fig. 133 is a good example of this kind of control where the mechanical operation remains un-

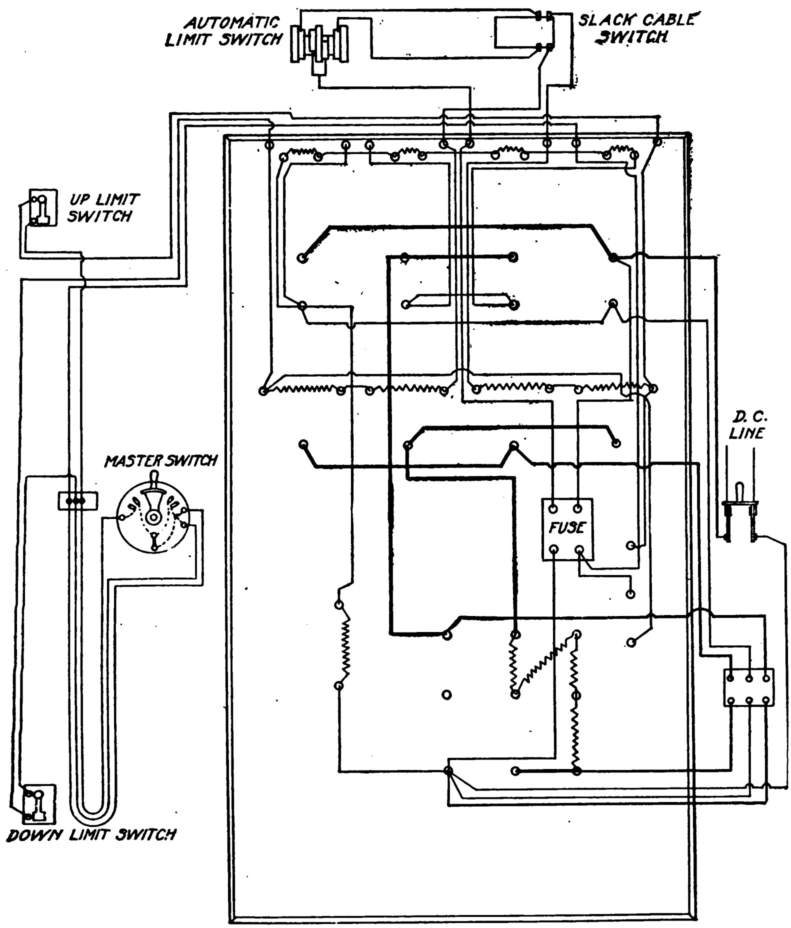


Fig. 134. Wiring Diagram of Single-Speed Full Magnet Controller

changed. *AA* are the switches used in closing the circuit for the *up* movement of the elevator, *BB* perform the same office for the opposite direction, and *D* is the solenoid for cutting out the several banks of resistance as the motion of the motor accelerates. The line switches are closed by means of the electromagnets C, the springs E automatically opening the switches when the current in C is cut off. The wiring diagram for a single-speed full magnet controller is given in Fig. 134. Fig. 135 shows the method used by another manufacturer to accomplish the same purpose. Where a variable speed is desired, a controller, Fig. 136, similar to Fig. 133, is used; the only difference is in the use of the extra solenoid, shown at the lower left-hand corner of the board, and the accompanying switches for cutting resistance into the motor fields for accelerating

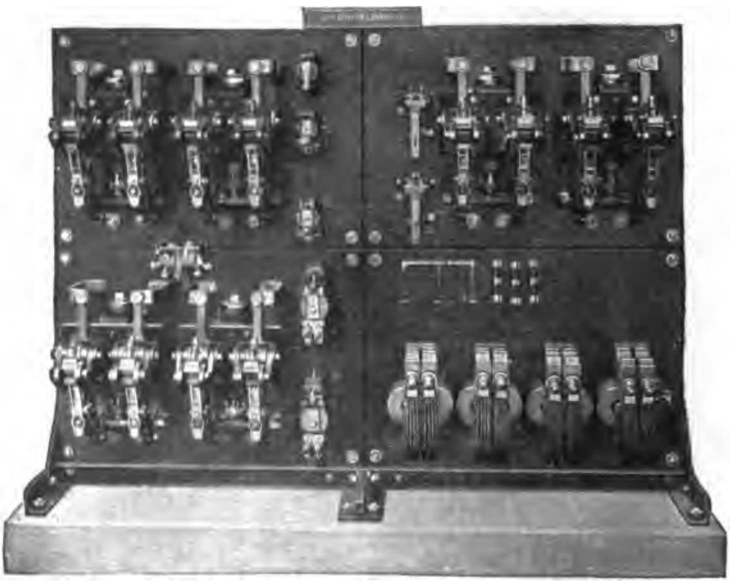


Fig. 135. Full Automatic Skip Hoist Controller for Alternating Current
Courtesy of Otis Elevator Company

the speed. This solenoid is energized by the movements of the car switch and is entirely under the control of the operator. The wiring diagram for a two-speed full magnet controller is given in Fig. 137.

Some elevator makers use a similar solenoid and switches on freight elevators, connecting the solenoid with the armature of the motor through special resistances so arranged that with light loads the solenoid is not energized, but under heavy loads the e. m. f. in the armature becomes great enough to move the plunger in the solenoid, which then operates the switches. In such cases, however, the action of the solenoid is different, as the operation of the switches cuts out resistance from the fields, thus causing the motor to run at a

Fig. 136. Variable-Speed Full Magnet Controller
Courtesy of Kaestner and Hecht Company

slower speed—the field resistance is always in, except when the solenoid is energized. The effect of this arrangement is to produce a fairly high speed with comparatively light loads; while with a heavily loaded car, the speed is automatically lowered by cutting out the field resistance.

Fig. 138 is similar to Fig. 136, except for two sets of switches for controlling field resistance, as well as a separate switch (the center

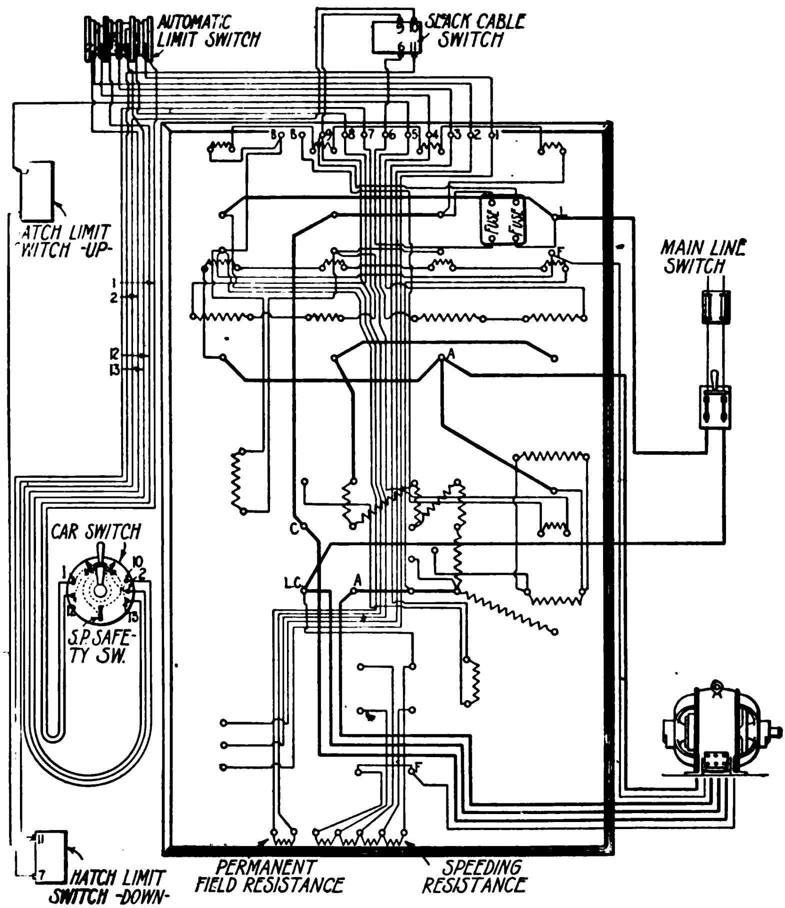


Fig. 137. Wiring Diagram of Two-Speed Full Magnet Controller

one, top row) for controlling the brake. This controller gives three speeds and is designed for use with motors equipped with interpole fields and heavy series winding, the action of which was described on page 169. Fig. 139 shows the wiring diagram for a three-speed full

Fig. 138. Three-Speed Full Magnet Controller for High-Speed Passenger Elevator
Courtesy of Kaestner and Hecht Company

magnet controller with interlocking magnet and an extra line switch for 500 volts direct current.

Push-Button Control. MANIPULATION. Elevators using push-

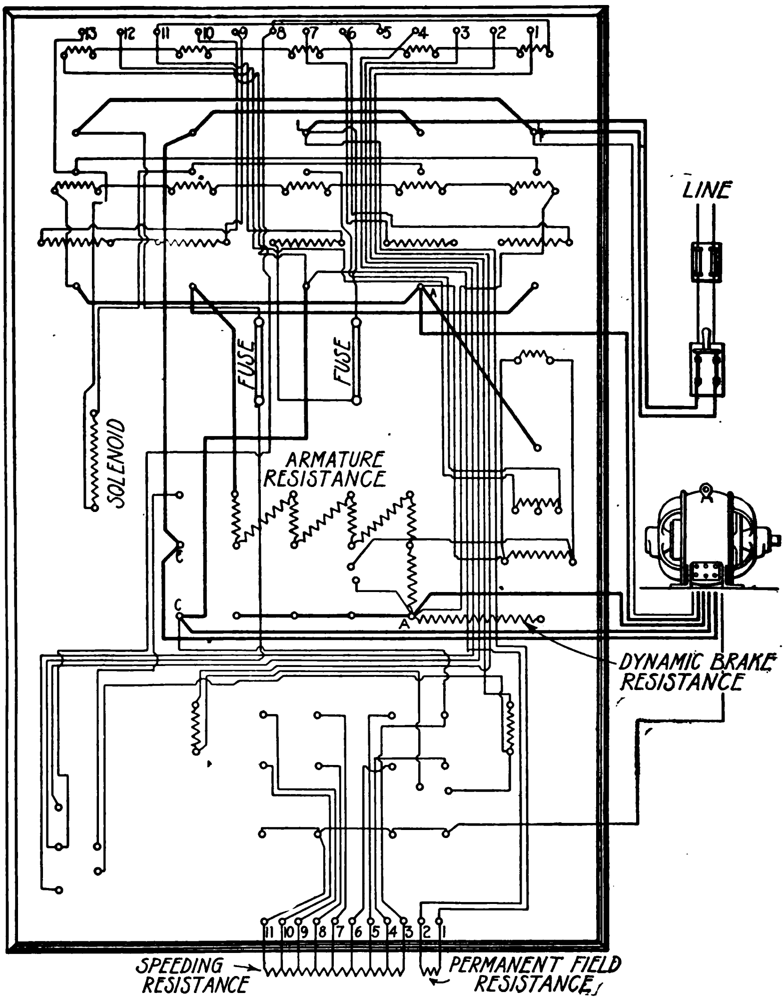


Fig. 139. Wiring Diagram of Three-Speed Full Magnet Controller with Interlocking Magnet and Extra Line Switch
Courtesy of Kaestner and Hecht Company

button controls are largely used in hospitals, apartment houses, and private dwellings. They are necessarily one-speed elevators and are intended to be operated by the passengers themselves. In Fig.

140 is shown a controller in its usual position near the engine; Figs. 141 and 142 show wiring diagrams for a.c. and d.c. current.

The manipulation of the automatic push-button elevator may be clearly understood from Fig. 143. The person desiring to use the elevator presses a push button near the elevator door (marked "Call Button"). The elevator at once comes to the floor at which the

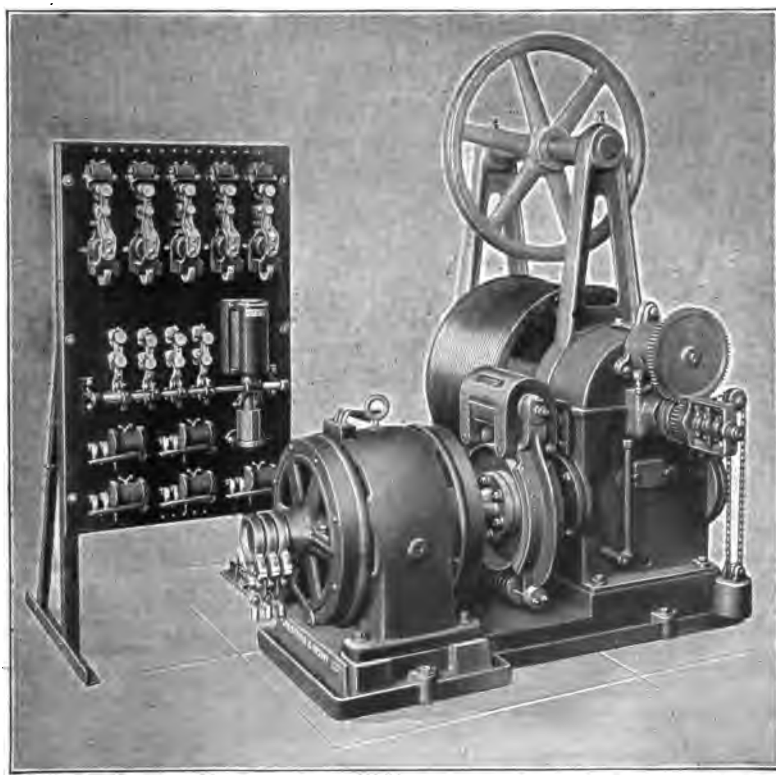


Fig. 140. Automatic Push-Button Controller and Machine
Courtesy of Kaestner and Hecht Company

operator is waiting and stops there. The door may now be opened, and after stepping inside the cab and closing the door, the operator selects from a bank of buttons inside the cab the one marked with the number of the desired floor and, upon pressing this button, the elevator moves to the floor designated and stops there. These push buttons are arranged one above another in a metal box, Fig. 144, and are connected by means of a flexible cable with the necessary wires which run in the proper conduits to the hatch switches and to the controller.

SAFETY DOORS. The doors to the shaft are so arranged that opening one of them breaks the circuit; consequently, if upon leaving the elevator at any floor the user fails to close the door after him, the

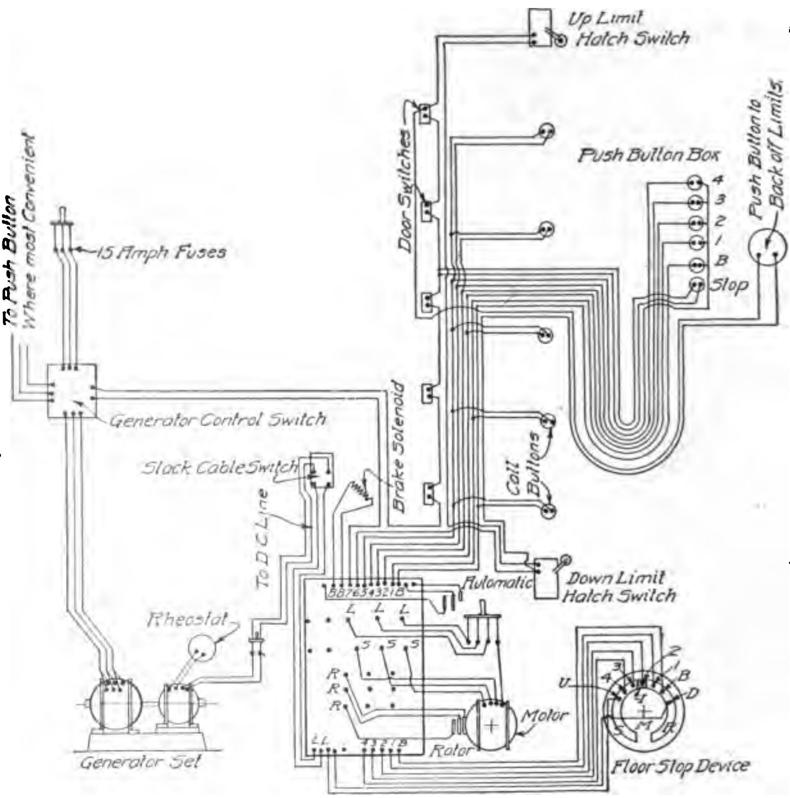


Fig. 141. Wiring Diagram of Five-Floor Automatic Push-Button Control for Three-Phase Motor
Courtesy of Kaestner and Hecht Company

elevator is out of service for the time being and cannot be started again until that door is closed. To prevent opening the elevator door when the car is not at the landing, a lock is provided which is released only when the car itself reaches the landing; this is accomplished by having a small cam on the car, which closes a switch, thus actuating a small electromagnet and unlocking the door. The circuits for this arrangement are shown in Fig. 143 and are given with sufficient clearness to be almost self-explanatory. The floor

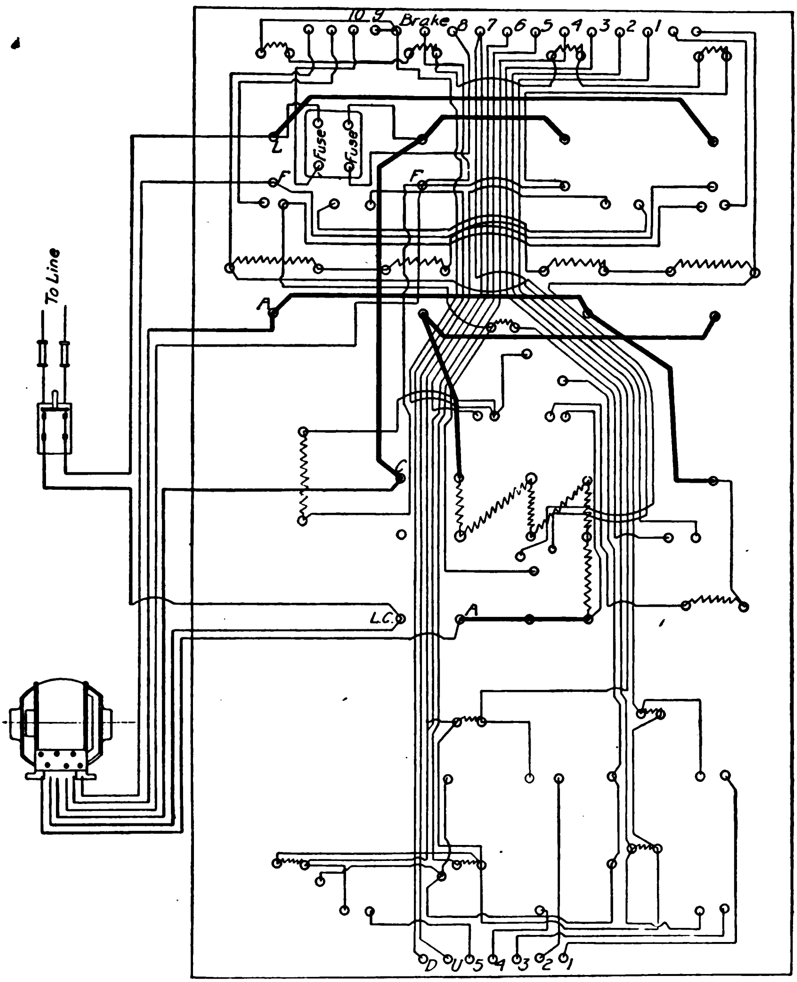


Fig. 142. Wiring Diagram of Five-Floor Automatic Push-Button Controller for D. C. Motor
Courtesy of Kaestner and Hecht Company

call buttons are on the right and the circuits leading to the car controller are clearly shown.

Up and Down Control. The up and down control of the push-button elevator, the wiring diagram of which is shown in Fig.

141, is accomplished by means of a floor-stop device as shown in the diagram. This device consists of an insulated disk *M* on which are mounted two brass annular segments *R* and *S* insulated from each other at *I* by a segment of insulating material. In front of the disk is a fixed frame containing brushes *D*, *B*, *1*, *2*, *3*, *4*, and *U*. These brushes are insulated from the frame and bear upon the annular segments of the disk as shown. The brush *D* is connected to the solenoid on the control panel operating the switches for a "down" direction of motion of the cage, while the brush *U* is connected to the solenoid operating the switches for an "up" direction of motion of the cage. The segment *R* may hence be called the "down" segment and the segment *S* the "up" segment in that they connect, respectively, with the switches for those particular directions of running.

The brushes *B*, *1*, *2*, *3*, and *4* correspond to floors and each is connected to a small electromagnetic switch shown at the bottom of the panel in Fig. 140, one electromagnetic switch being provided for each brush.

Fig. 141 is drawn on the assumption that the car is at rest at the second floor, in which case brush *2* is on the insulated segment *I*. Assume now that the fourth-floor call button or the fourth-floor button in the car is pressed. The momentary pressing of the button will operate the corresponding electromagnetic switch for that floor at the bottom of the panel. The switch will complete the circuit of the solenoids operating the main switches for an upward movement of the cage, through the brush *4*, the "up" segment *S*, and the brush *U*. The car will hence move upwards. In so doing the disk *M* will be caused to revolve in a counterclockwise direction, as it is connected to the cable drum or a cable sheave by means of a chain and sprocket wheels which give the disk a motion proportional to the motion of the cage and a direction of motion dependent upon the motion of the cage.

Hence the rotation of the disk *M* will cause the insulated segment *I* to move to the left. It will then pass under the brush *3*, and after its passage the brush *3* will bear on the "down" segment *R*, but the car will continue to move upwards, as the "up" switches were closed through brush *4*. When brush *4* bears on the segment *I*, it, of necessity, ceases to bear on the "up" segment *S*, and hence the circuit to the "up" switch solenoid and the brake-release solenoid is broken and the car stops. Now the disk is so geared to the cable

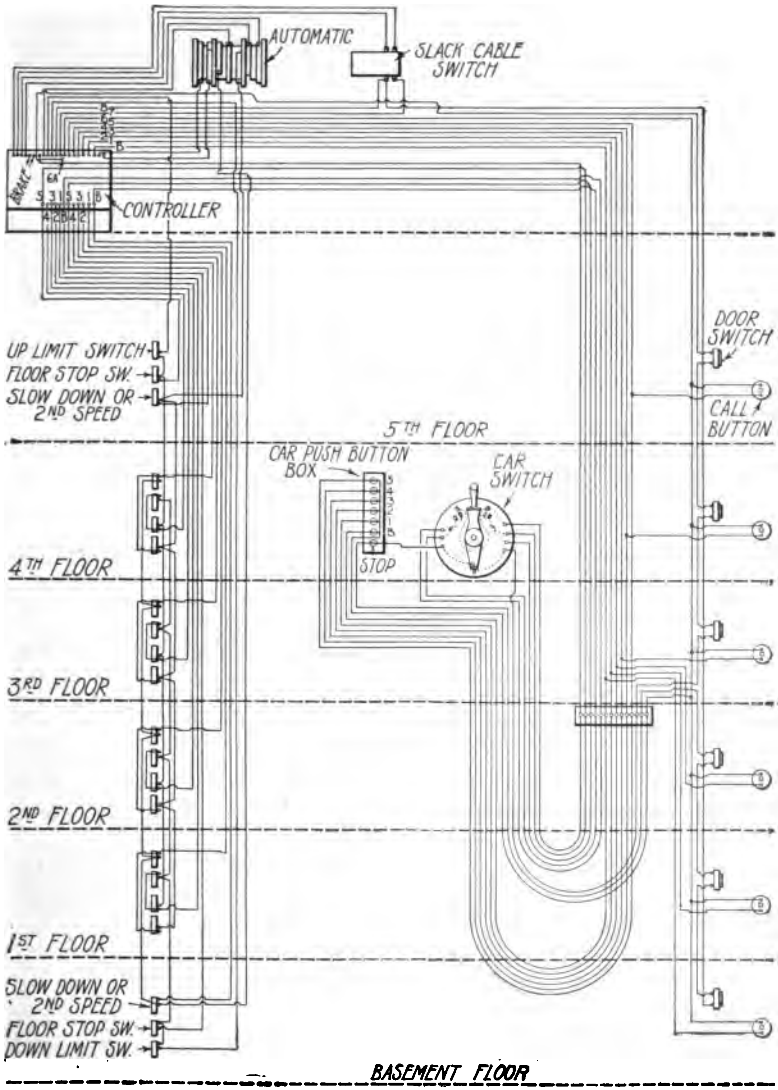


Fig. 143. Hatch Wiring Diagram of Six-Floor Combination Two-Speed Car Switch and Push-Button Control Elevator
Courtesy of Kaestner and Hecht Company

drum or to a cable sheave by sprocket wheels and a chain that when a brush is on the segment *I*, the car is at the landing corresponding to that brush. Hence in the case under consideration the car will stop at the fourth floor. It is seen that by this arrangement the brushes *B*, *1*, *2*, *3*, and *4* are made to pass from one segment to the other as the car passes a floor, hence placing each of the brushes on the segments that will give the car the correct direction of motion for traveling to the floor desired by the passenger, when the correct push button is pressed.

Fig. 144. Warner Cab Push Buttons

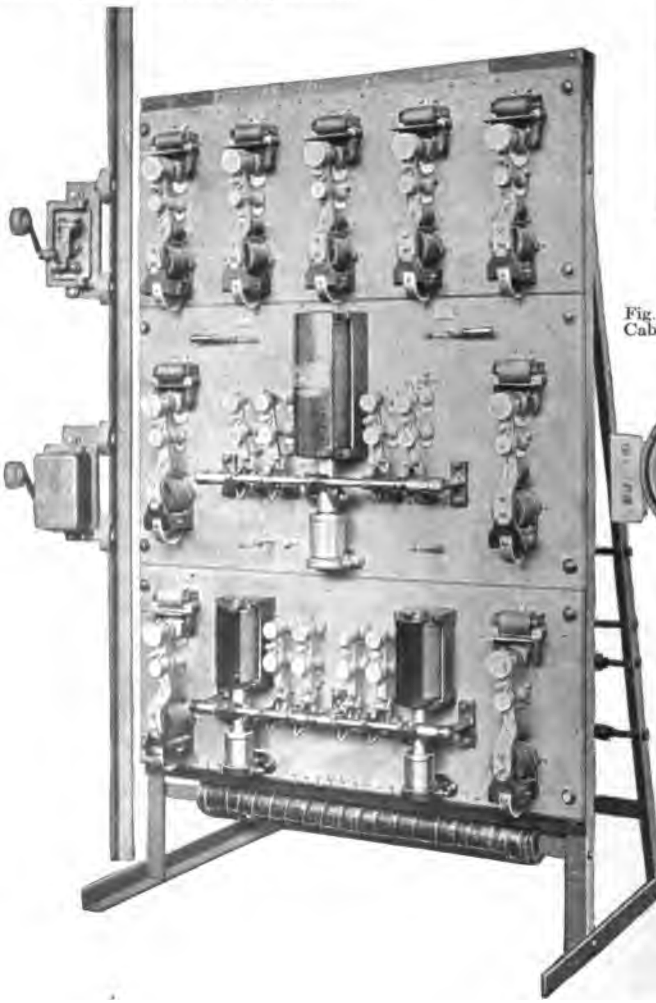


Fig. 145. Variable-Speed Full Magnet Elevator Controller
Courtesy of Kaestner and Hecht Company

The preceding description makes clear the method of push-button control when an alternating-current motor is used. In those cases where the direct current is used exclusively for operating the elevator, extensive modifications of the circuits must be made, as will be seen from the diagram shown in Fig. 142. However, the method of control is essentially the same as far as the manipulation in the car and at the various floors is concerned.

Referring to Fig. 140, it will be seen that there are five switches arranged at the top of the controller board; the two outer ones on either side are the line switches, while the center one is for closing

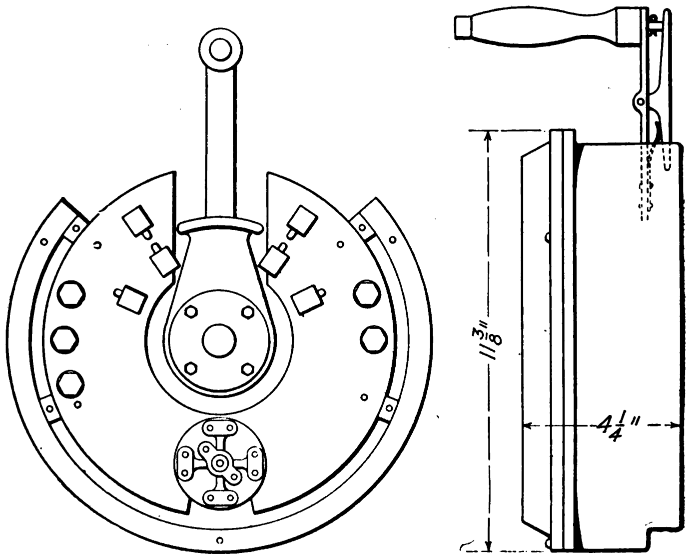


Fig. 146. Front and Side Elevations of Car Master Switch

the circuit to the brake. The four smaller switches and solenoid just below are as usual for controlling the acceleration of the motor. The five small spools at the bottom of the board are electromagnets for closing the line and brake switches and are operated by the push buttons and disk switches. As one of these small electromagnets is required for each floor, the machine shown in the illustration is a five-floor controller.

The bank of push buttons in the cab comprises one button for each floor, appropriately numbered, and one button marked "STOP", Fig. 144, to be used in case the operator makes a mistake. If he selects the wrong floor, he simply pushes the "STOP" button and makes his selection anew.

Motor. The motor, Fig. 140, is an alternating-current three-phase motor. It might be mentioned here that any single-speed elevator may be operated on alternating current with magnetic control by using a small motor-generator set comprising an alternating-current motor and a direct-current generator to generate sufficient direct current to operate the electromagnets and solenoids for the control. (See the circuits for this arrangement at the lower left-hand corner of Fig. 141.) This small transformer set would run constantly and need not produce more than 10 to 20 amperes at 110 volts, the amount of current depending upon the capacity of the elevator. Most of the current would be used by the solenoid which releases the brake, the rest of the control never requiring more than 4 amperes.

Fig. 147. Otis Direct-Current Elevator Controller

Variable-Speed Controller. The controller used for variable-speed elevators, running from 300 to 600 f.p.m., is shown in Fig. 145. Of the five switches located on the upper panel, the two outside ones on either side are the line switches, as before, while the center switch manipulates the field. In the center of the middle panel are the solenoid and the switches for cutting in and out the resistance in starting up on the first speed; the switch to the right in the same panel operates the dynamic brake; and that on the left operates an extra set of shunt fields used in connection with high-speed elevators for the purpose of giving still greater torque at starting, these shunt fields being auxiliary to the regular shunt fields of the motor. In the lower panel are located the switches and cut-outs of the two other speeds used in accelerating after starting.

To the right of this controller board is the operating switch which is mounted in the car. This is shown diagrammatically in Fig. 146. Moving the handle to the right produces motion of the car in one direction; and to the left, the reverse. It is so constructed that should the operator remove his hand from the lever, it will automatically assume the stop position shown in the cut. Just below this lever near the lower part of the case is a button, Fig. 145, which operates the emergency switch for opening the circuit in case of accident to the lever or its connections. At the left side of the case and attached to it is a small white panel carrying the reset for the circuit breakers which are used in connection with this type of elevator. These circuit breakers, in case the elevator should be overloaded or the voltage on the line become either abnormally high or low, will of themselves automatically open the circuit, thereby protecting the motor from the danger of burning out.

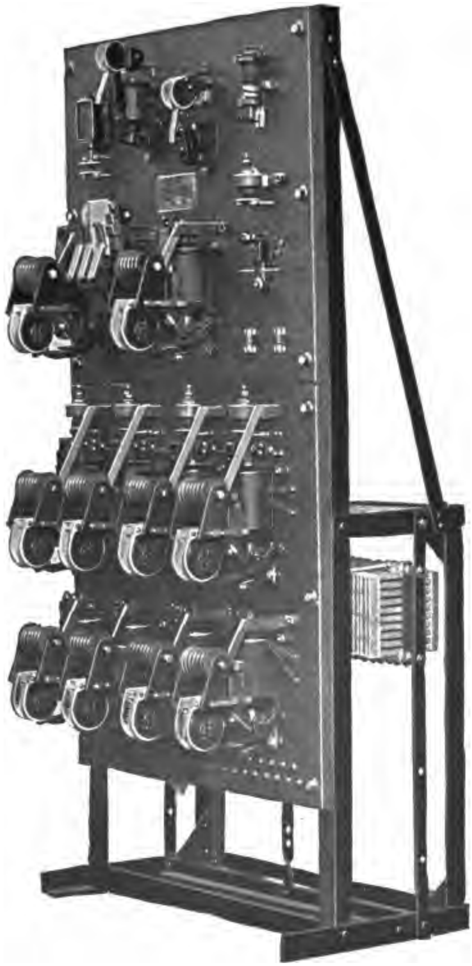


Fig. 148. Haughton Type of Controller
Courtesy of Haughton Elevator and Machine Company

At the extreme left of the illustration is a section of one of the steel guide rails in which the counterpoise weight travels. This has attached to it two hatch switches, already referred to as being used for the purpose of slowing down and stopping the car at each end of its run. A cam attached to the car presses back the lever shown at the side of the switch, thus producing the desired results. The upper switch is shown with the cover removed. These switches are clamped to the guide rail in such a way that they may be readily

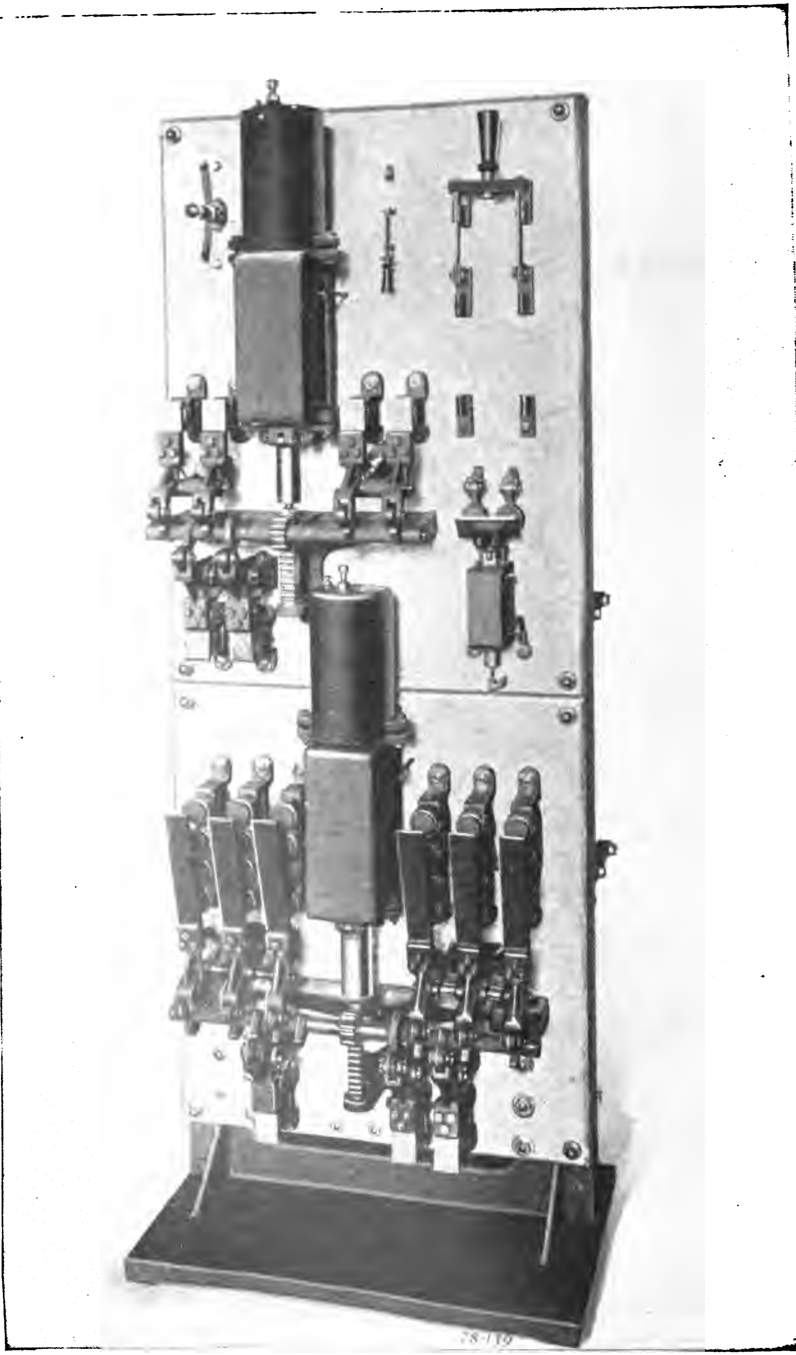


Fig. 149. Gurney Type of Controller
Courtesy of Gurney Elevator Company

adjusted for position with respect to the upper and lower landings, and in actual use are set several feet apart, instead of close together, as shown in the illustration.

A close observation of the panels of the two- and three-speed controller (Figs. 136 and 138) will show one or more single-pole knife switches. These are used for the purpose of throwing out of service the extra speeds, thereby converting the machine into a single-speed elevator for the time being; by this means an elevator designed to lift a moderate load at a high speed may be used for lifting a heavy load at about half speed. This arrangement, while useful for an occasional load, is not intended nor is it suitable for continuous service, being liable under such conditions to overheat the motor windings.

For the foregoing illustrations we have selected representative types of one of the best manufacturers. To illustrate differences in design, controllers of other standard makes are shown in Figs. 147 148, and 149.

TRANSMISSION

The motor and controller having been discussed, only the transmission needs to be considered in order to complete what is usually known by elevator builders as the *electric engine.*

Location of Engine. The different forms of transmission vary somewhat with the location of the engine. This is, in some cases, placed on a foundation in the lower story, Fig. 150, or alongside the hatchway on any other floor of the building, but the most usual location is directly over the hatchway or shaft, Fig. 151. A penthouse is made especially for it above the roof, the engine resting on a floor supported by steel I-beams which, in turn, are carried by the walls of the building and the hatchway. The engine is securely bolted to these beams and slots are cut through the floor for the passage of the cables which connect the winding drum with the car and counterweights. The latter arrangement has the advantage of a more direct connection between the engine and the car and the elimination of the overhead sheaves which are necessary when the engine is located below and adjacent to the hatchway. The placing of the engine overhead does not always do away with the necessity for overhead sheaves for, where the hatchway is large or the necessary location of the engine is such that the diameter of the winding will

Fig. 150. Basement Type of High-Speed Passenger Elevator with Full Electric Control
Courtesy of Warner Elevator Manufacturing Company

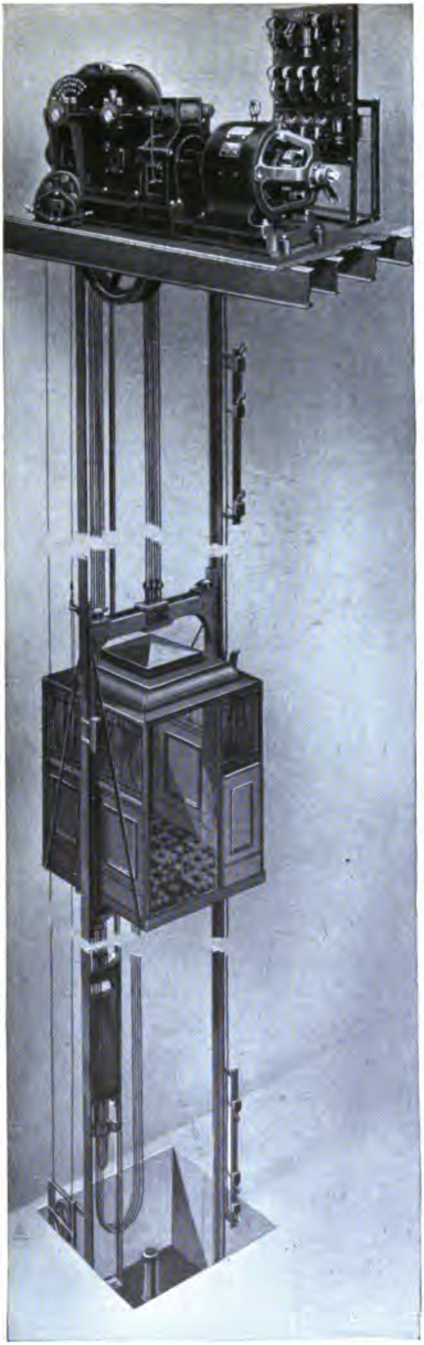


Fig. 151. Overhead Type of Passenger Elevator for Heavy Duty with Full Magnet Control
Courtesy of Haughton Elevator and Machine Co.

not span the distance from the center of hatch to center of weight slides, auxiliary sheaves become a necessity.

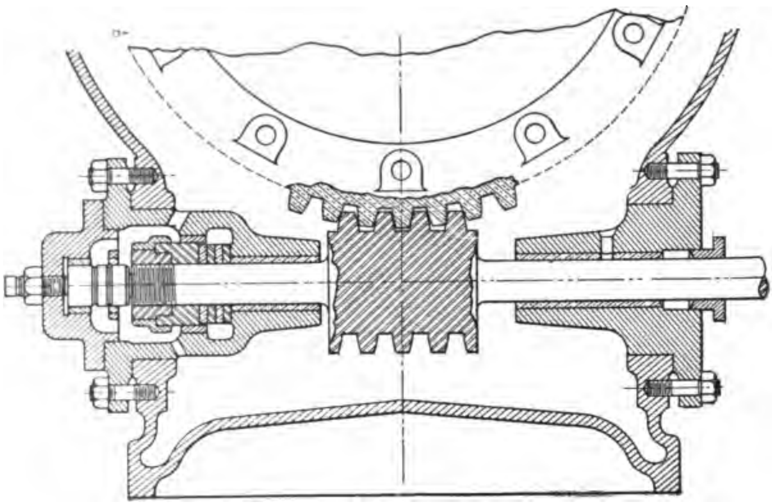


Fig. 152. Single Gear Worm and Wheel

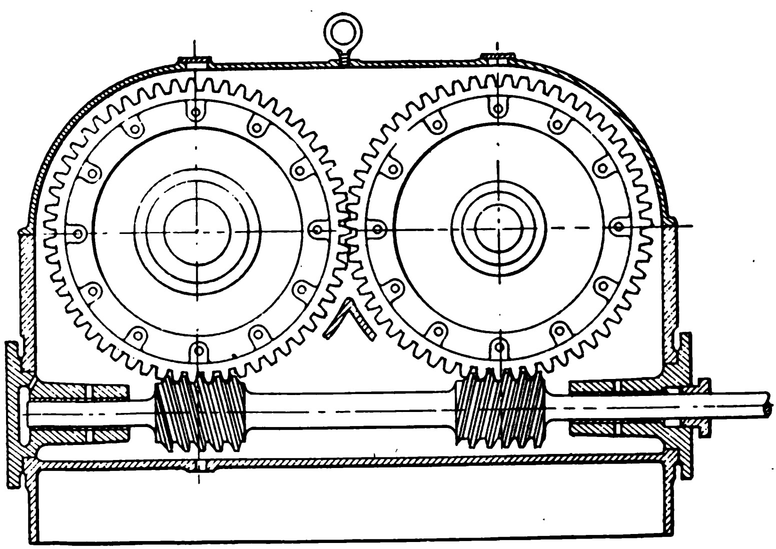


Fig. 153. Tandem Gear Which Avoids End Thrust

It cannot be doubted though that when the engine is placed overhead, a great deal of friction is dispensed with, and some room

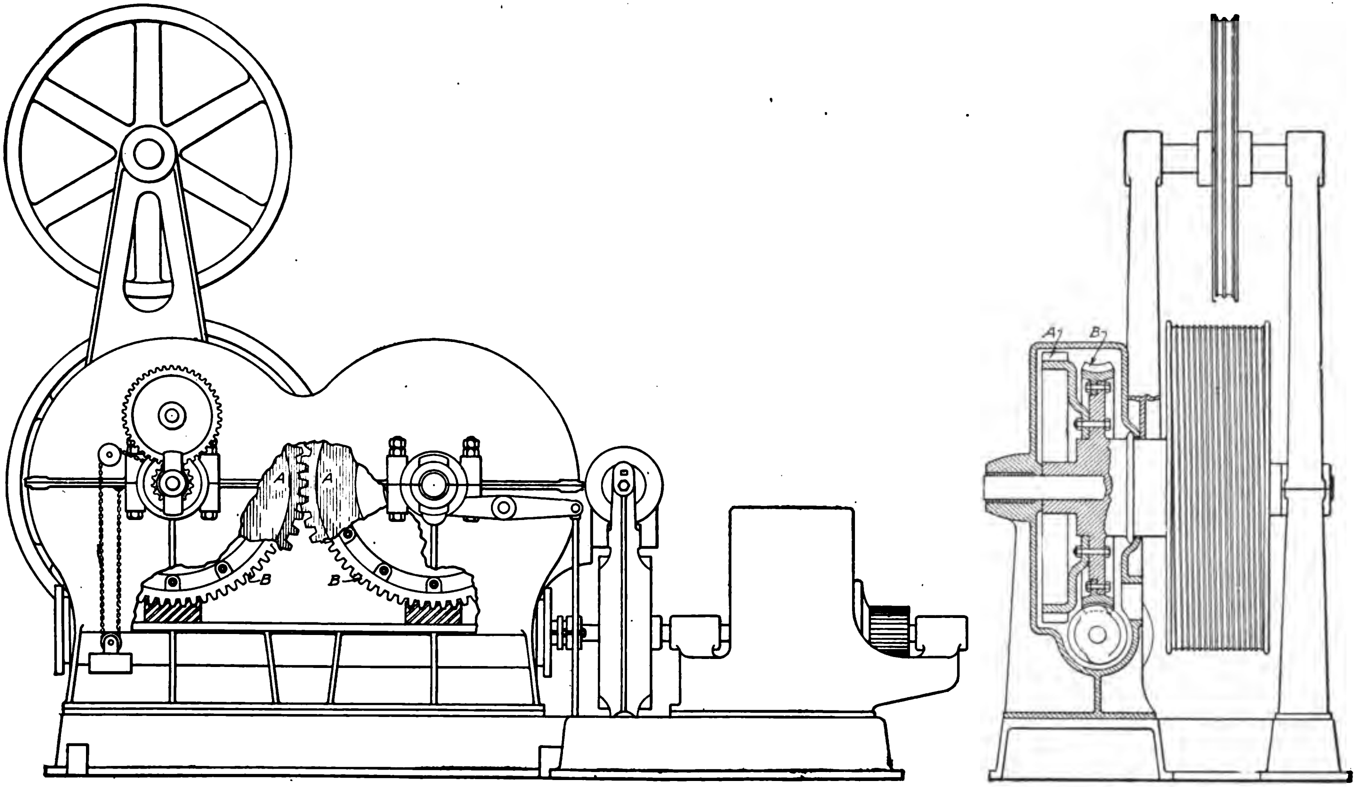


Fig. 154. Early Design of Spur Gears and Tandem Worm
Courtesy of Kaestner and Hecht Company

in the building saved for other uses. This arrangement calls for either brick walls surrounding the hatchway or girders at the roof sufficiently strong to carry the weight of the engine, car, counterpoise weights, and loads to be lifted, as well as the weight of the wall and roof of the pent house. The support must also be strong enough to resist the impact caused by the stopping and starting of the elevator.

Worm and Wheel. *Single Gear.* The power of the motor is transmitted to the winding drum and thence to the car or platform by means of a mechanism called a worm and wheel, Fig. 152 The shaft on which the worm is cut is direct-connected to the armature shaft of the motor by means of an insulated coupling (see Fig.

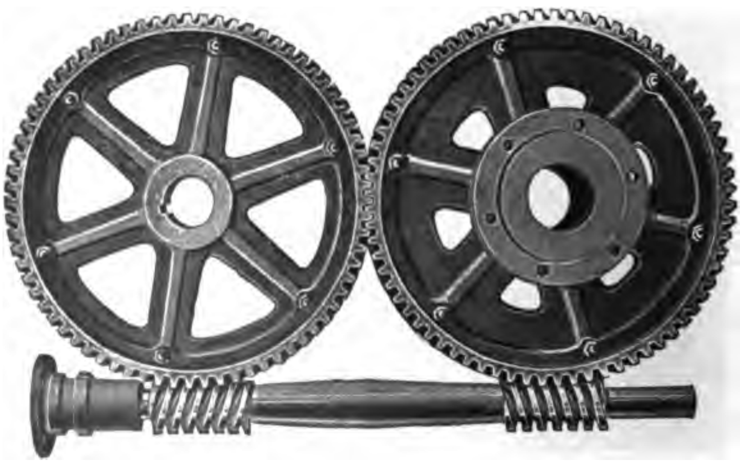


Fig. 155. Gurney Tandem Worm Gear Drive

126), one-half of which is shaped like a pulley of very heavy design and liberal width of face. This coupling serves as a brake pulley for use in stopping the machine and for holding it while being loaded and unloaded.

Tandem Gear. Another type of worm gear—called the tandem gear—is quite an old idea, having been patented over thirty years ago by a Boston firm. It consists of two worms or coarse pitch screws, Fig. 153, usually forged solid on one shaft; one screw being cut with a right-hand thread and the other with a left-hand thread. As originally designed by the inventors, the worm gears used were made with straight faces—the teeth being cut at the angle of the thread of the worm—and the gears were set so that they meshed together. Later some makers used spur gears in addition to two worm wheels, Fig. 154, and bolted them together in pairs. The wheels were made with concave faces and teeth, as shown in the end elevation at the right, and the spur gears were enough larger in diameter than the worm gears to prevent the latter from touching each other when the spurs were in mesh.

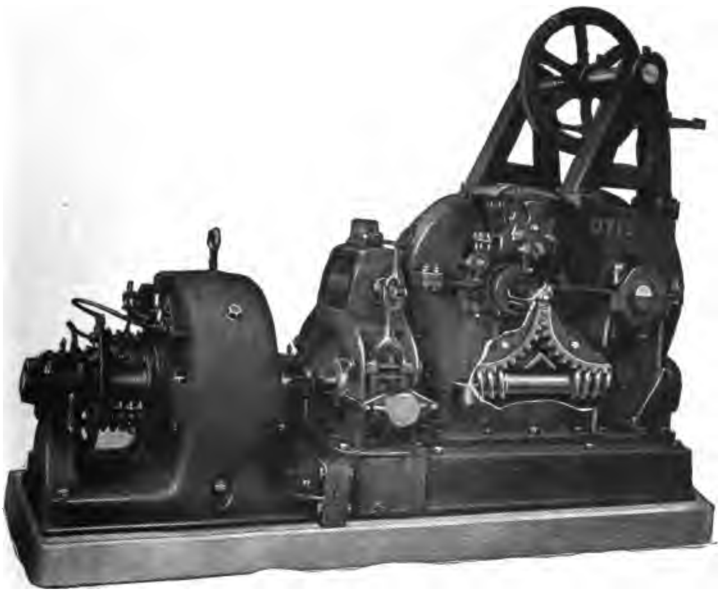


Fig. 156. Double-Screw Direct-Current Elevator Machine with Switch Control
Courtesy of Otis Elevator Company

Another and better way to secure these advantages is to use two spiral gears meshing together with the worms driving them, as shown in Fig. 155. Fig. 156 gives the general appearance of a tandem-geared engine.

The advantages claimed for the tandem-geared engine are double power and durability. The load, being divided between two worms and gears, produces only one-half the strain on the teeth of each, but it is a more expensive machine to build and occupies more space. However, for heavy loads the arrangement is certainly preferable to a single-geared machine having an enormous gear and drum. Another advantage is that the gears used in the tandem machine are about the same size as those in general use, and therefore no special patterns or tools are required for the production of a machine of double capacity except the gear case and the bed, or base plate, of the engine. This tandem construction also eliminates the end thrust, which is discussed on page 204.

Provisions for Speed and Load Variations. *Change of Gear Pitch.* In all these machines it is customary to so design the gear cases that a choice of any of two or three pitches of gear and worm may be used, the range for the smaller sizes being from $\frac{7}{8}$-inch to $1\frac{1}{8}$-inch pitch, Fig. 157, with lifting capacity of 1500 to 3000 pounds, and from $1\frac{1}{4}$-inch to $1\frac{3}{4}$-inch for the heavier capacities. As the worm gear only moves the space of one tooth for each revolution of the worm shaft, the latter must revolve as many times as there are teeth in the gear for each revolution of the drum; so if the drum, in order to make the car travel at the required speed, had to make 15 r.p.m. and the worm gear had 50 teeth, the speed of the worm shaft and consequently that of the motor would have to be 750 r. p. m. A different speed of the drum may be brought about by a choice of any one of two or three pitches of worm gear. Of course, the same result could be accomplished by modifying the diameter of the drum, but this has some limitations in that the drum must not be so small in diameter as to have a bad effect on the cables, nor so large that the pressure between the teeth of the gear and threads of worm will cause excessive wear.

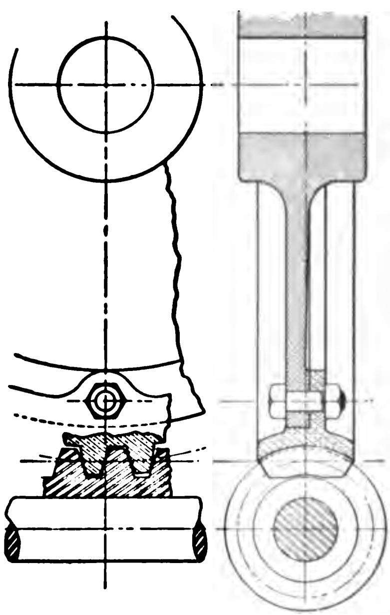


Fig. 157. Diagram Showing Arrangement for Changing Gear Pitches

Double-Threaded Worm. Where greater speed of car is desired, a double-threaded worm may be used, thus giving double speed to the drum. Therefore, in a machine built so as to allow a choice of any one of three gears and worms, and, in addition, the double pitches just spoken of, there are six available speeds. These are capable of further variation either by the use of high-speed or low-speed motors or by varying the diameter of the hoisting drum, thus providing a possible variation of car speed of from 100 to 200 f. p. m.

Reduction Gear. When a car speed of from 50 to 60 feet is desired, it is customary to reduce the number of revolutions of the drum by means of a reduction gear, Fig. 158. The gear used in this machine is a spur of the "internal" type and, as the pinion usually

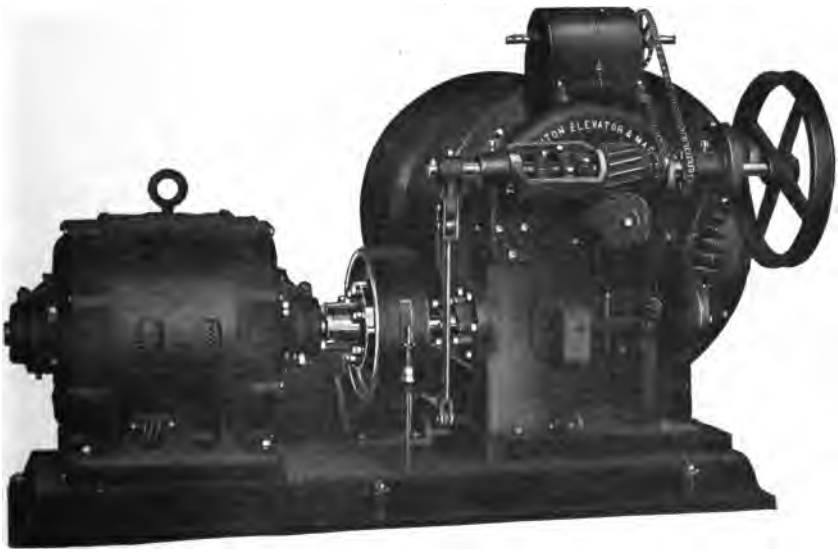


Fig. 158. Internal Gear Type of Drive
Courtesy of Haughton Elevator and Machine Company

has a ratio of about 4 to 1, a high speed motor may be used. Of course when the reduction gear is used, the pinion is placed on the same shaft as the worm gear and the drum runs in separate bearings. The principal reason for the use of an internal spur gear is that it does not change the direction of the drum's rotation, while a spur gear of the ordinary type would. It is always best that the drum in lifting the load should revolve so as to bring the thrust of the end of the worm shaft towards the back end of the gear case.

End Thrust of Worm Shaft. In order that the reader may have a clear idea of the action of the end thrust of the worm shaft in a direct-connected single-gear machine, the details of the back bearing are given in Fig. 159. An examination of Fig. 152 shows that this end thrust is a very important thing, as upon the resistance of the back bearing depends the lifting power of the machine. The bearing shown is the most common form of thrust bearing and is so arranged that the end thrust is capable of adjustment in both directions. For the back thrust, a steel toe or thrust plug with a taper shank fits into a hole bored in the end of the worm shaft at *B*, Fig. 159. This is held in place by another steel plug *C*, with a hard bronze disk

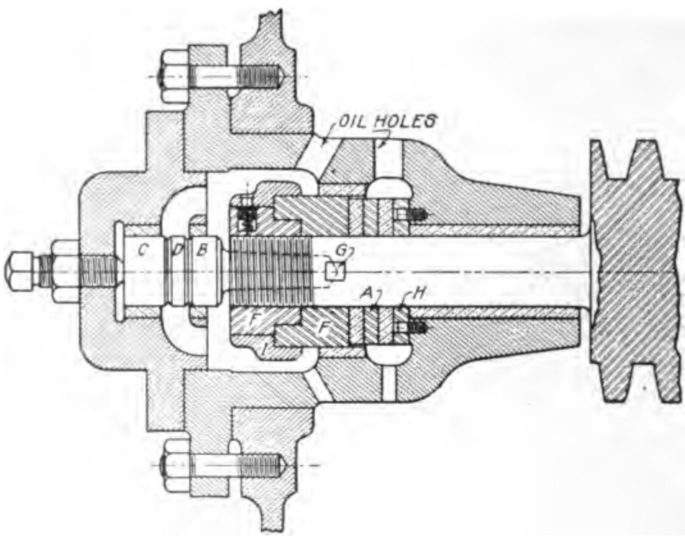


Fig. 159. Section of Worm Shaft Thrust Block

D between them. This steel plug *C* is adjustable for wear by means of a set screw, and is kept from revolving by a pin, not shown. The bronze disk, however, is free to revolve with *B* and bears the brunt of the wear.

The forward thrust due to the action of the counterpoise weights is taken on the alternate steel and bronze rings *A*, which are also free to revolve; the steel collar *E* is kept from revolving by the pin *G*, but has a longitudinal slot in it which fits over *G* and allows some end motion. The nut *F* is screwed on the end of the worm shaft and, by tightening up this nut when necessary, any lost motion in the forward thrust may be eliminated. The nut is kept in place by the keeper *I*. That part of the gear casing which contains this thrust compensator also serves as the back bearing for the worm shaft. It is bushed or lined with bronze, and oil holes are provided for free access of oil from the reservoir which lubricates the worm and gear.

This device is but one example of the many contrivances of this nature and is sufficient to illustrate the method of taking care of the end thrust. Some makers use steel balls between the thrust plates with a view to reducing friction to a minimum. Fig. 160. There are some objections to the use of balls as they are liable to crush under heavy loads, the lost motion cannot be so easily taken up, and they wear grooves in the plates or rings. Some makers consider that the oil from the reservoir which lubricates the worm and gear is liable

Fig. 160. Ball Bearing Thrust Block for Worm Shaft
Courtesy of Warner Elevator and Manufacturing Company

to contain grit and cuttings from the gear and, therefore, prefer to lubricate the thrust bearing by means of a special oil cup in the outside of the gear casing.

Winding Drum and Cables. Elevators which have a travel of less than one hundred feet seldom are made to run at a speed of more than two hundred and fifty f. p. m., and more frequently less than that. In the case of what is called the "drum" type of machine, the lifting and drum counterweight cables are attached to the drum, which is grooved spirally with a concave groove to receive and guide the cables. Each cable, or to be more accurate each pair of cables, has a separate groove, for there are but two grooves on the drum, and the cables are so attached and arranged that, while the lifting cables are being wound up, the counterpoise cables which are also attached to the drum, are being unwound. A careful inspection of Fig. 150 will enable one to follow the two sets of cables to the car and counterpoise weights. The "idler" pulley slides from side to side as the cables wind on or off. It is seen, therefore, that in pairs they alternately use the same grooves. These grooves, or scores as they are called, are, in the case of the overhead type, so made that they run

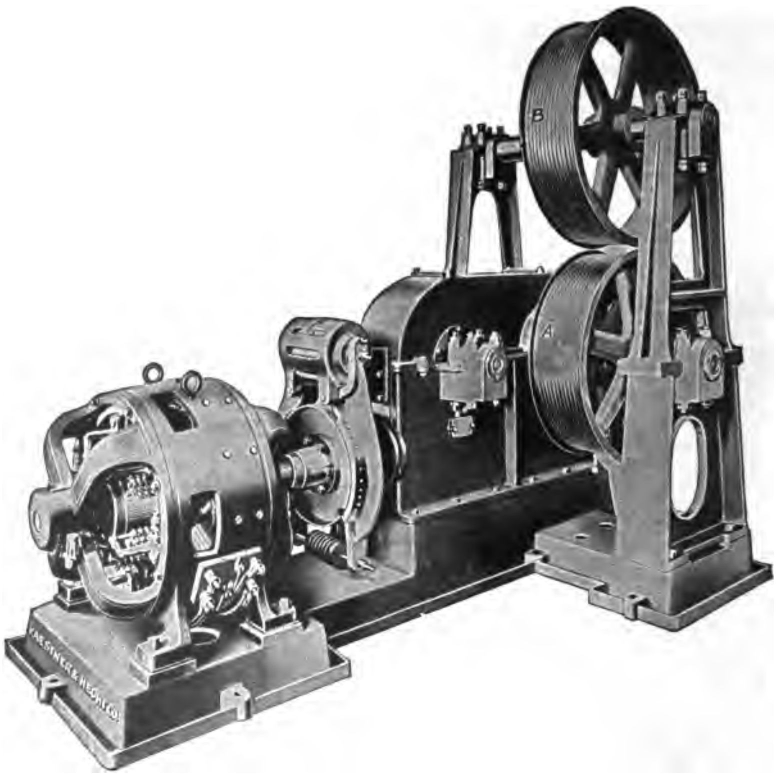


Fig. 161. Heavy Duty Tandem-Gear Traction Machine

from the ends of the drum towards the center, one groove on each side; when the engine is set to one side of the hatchway, either on a foundation or on suitable framing on one of the other floors of the building, the grooves run in pairs side by side from one end of the drum to the other and are made to lead right hand or left as the conditions require.

Counterpoise Weights. Two counterpoise weights are used: one which is attached to the drum to offset a certain percentage of the load to be lifted; and another used to counterbalance the car. The latter weight travels in the same runways as the drum counterweight, but above it, grooves or channels being cast in this upper weight to allow the supporting cables for the lower weight to pass through. The cables from this upper, or car, counterpoise pass up the hatchway and over sheaves or grooved wheels set at the top of the hatchway and thence down to the car itself, Fig. 150. It will be seen from the above description that in all six cables are used, and as the principal cables are rigidly attached at one end to the winding drum, the relation of the car to the number of revolutions of the drum is

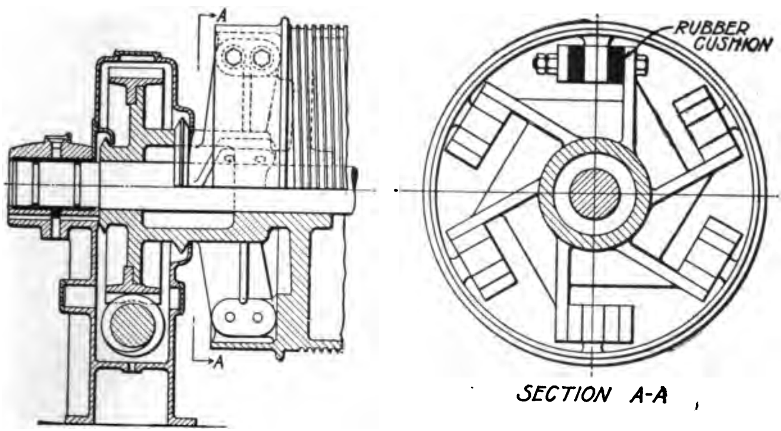


Fig. 162. Diagram Showing Six-Armed Yoke for Driving Traction Elevator

always fixed. It is evident, then, that a mechanical automatic limit stop, driven from the drum shaft itself, will always be sure to stop the engine at the end of the car travel.

TRACTION ELEVATORS

The transmission previously described is designed for vertical lifts of one hundred feet or less. When the car travel is from one hundred twenty-five to two hundred fifty feet, new conditions prevail. *First,* the speed must be greater or the elevator will require too great a time to make a round trip and will, in consequence, prove inadequate for the service required; *second,* the drum face required to wind up so much cable will be too wide to be practical in an ordinary width of hatchway; and *third,* the weight of such extreme

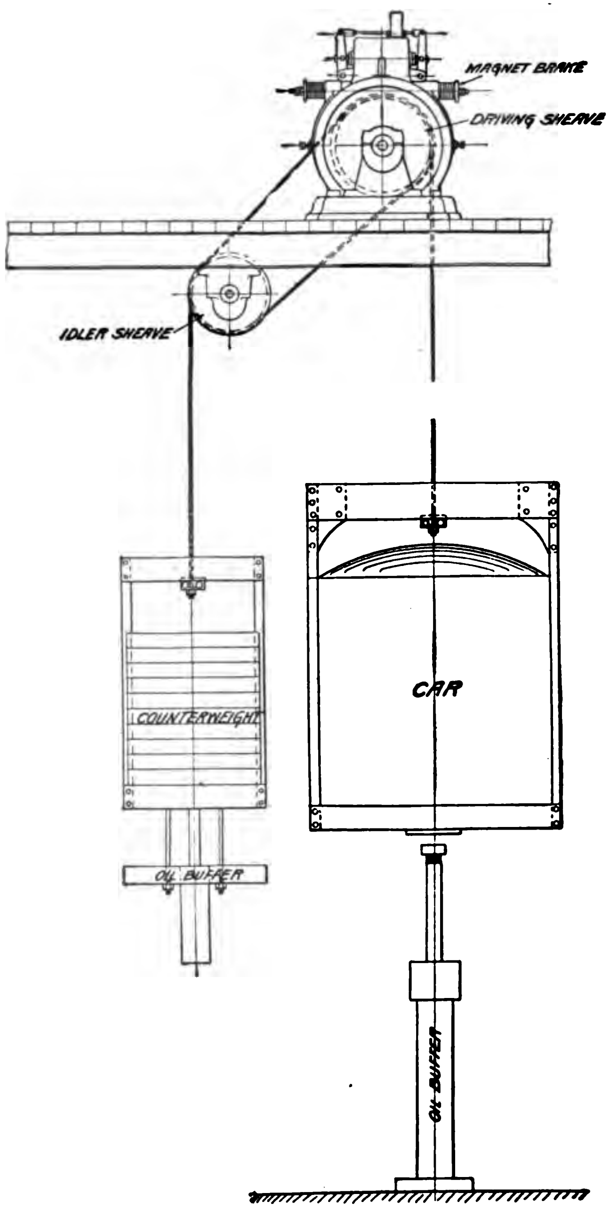


Fig. 163. Diagram Showing General Arrangement of Roping for Traction Elevator
Courtesy of Otis Elevator Company

lengths of cable will cause a series of vibration in the lifting capacity of the machine. To overcome these difficulties, another type of machine, called the traction elevator, has been devised.

Drum and Cable Arrangement. In engines of this type the wide faced drum is not used, being replaced by a drum not more than 12 inches wide, *A*, Fig. 161, with twelve grooves which are no longer spiral but are separate and distinct grooves such as are turned in a sheave; in fact, the drum is simply a sheave having more than the usual number of grooves. This drum is attached to or driven by the gear through a spider or six-armed yoke, Fig. 162, which engages with the arms of the drum. Rubber cushions are inserted at the points of contact to help soften any jar occurring at stopping and starting, and are held in position by suitable bolts and plates. Directly below or above this drum—according to whether it is an overhead engine or one arranged to be below on a foundation—is placed the "idler" sheave or drum *B*, Fig. 161, with the same number of straight grooves turned on its periphery, and running independently of the machine on a shaft and bearing of its own.

The cables are six in number and are passed over one of these drums and under the other in succession, Fig. 163. It is, however, always so arranged that they go twice partially around the engine drum and only once on the idler, although frequently, before leading into the hatchway, they are deflected by the idler in order to lead them plumb over the weight or over the car or into the hatchway, as the case may be. This accounts for the necessity of having the same number of grooves in each drum. One end of each of these cables is attached to the car and the other end to the counterpoise weight. It will be seen, therefore, that the cables are not attached to the drum at all, but depend on the friction with the face of the driving drum to transmit the power from the drum. Hence, the name *traction* machine. Figs. 161, 164, and 165, give a good idea of the machines of this type.

Limit-Stop Arrangements. *Hatch Switches.* With the arrangement of drum and cable just mentioned, the same width of face of drum will do for any height of car travel, but as the cables are not attached directly to the drum, the use of a mechanical limit stop is inexpedient, owing to a slight amount of slippage due to the stretching of the cables, quick starts and stops, and other causes. On this account a limit stop which was actuated by the engine would not remain accurate for long. This uncertainty has been removed by

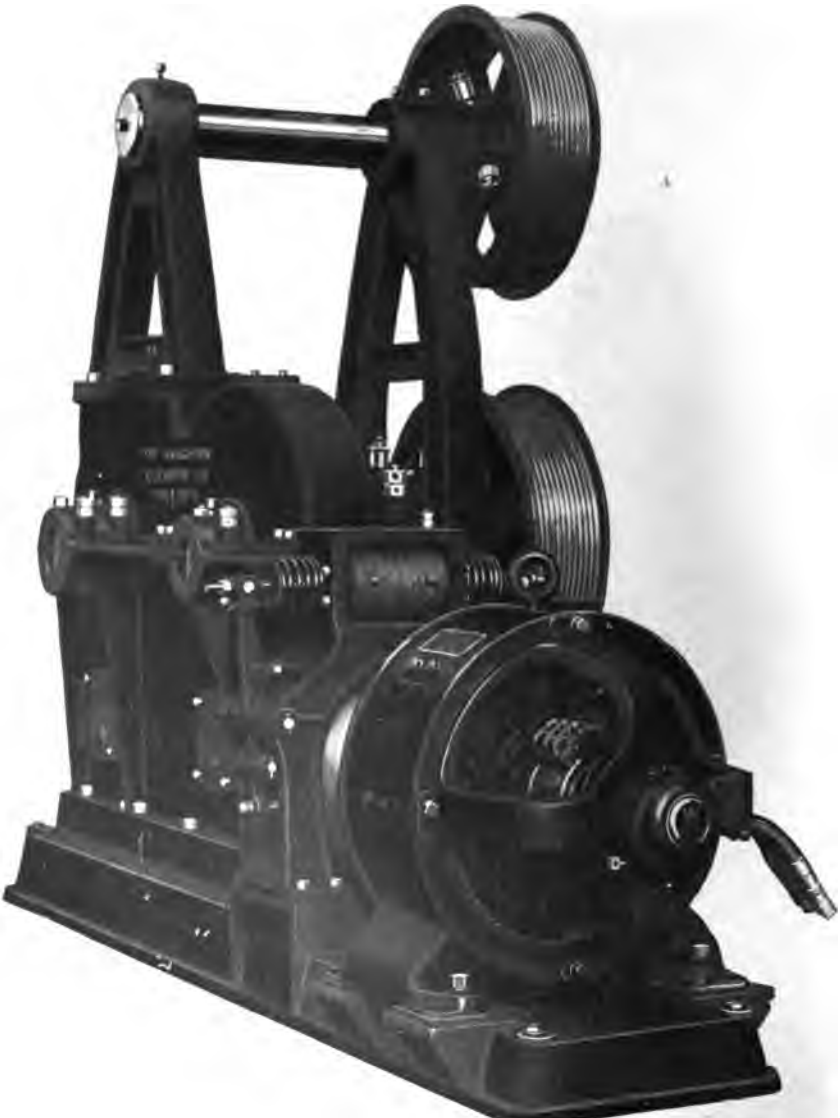


Fig. 164. Haughton Type of Tandem-Gear Traction Elevator
Courtesy of Haughton Elevator and Machine Company

the use of hatch switches, as shown at the left of Fig. 145. These switches are attached within the upper and lower limits of travel, usually to one of the guides, so that the car in passing pushes back a lever and thereby opens or closes a circuit as required. For high speed three of these switches are used at each limit of travel: the first to slow down, the second to stop, and the third as an emergency switch, setting fairly close to the stop switch, which closes a circuit to a solenoid, thus applying an extra squeeze to the brake.

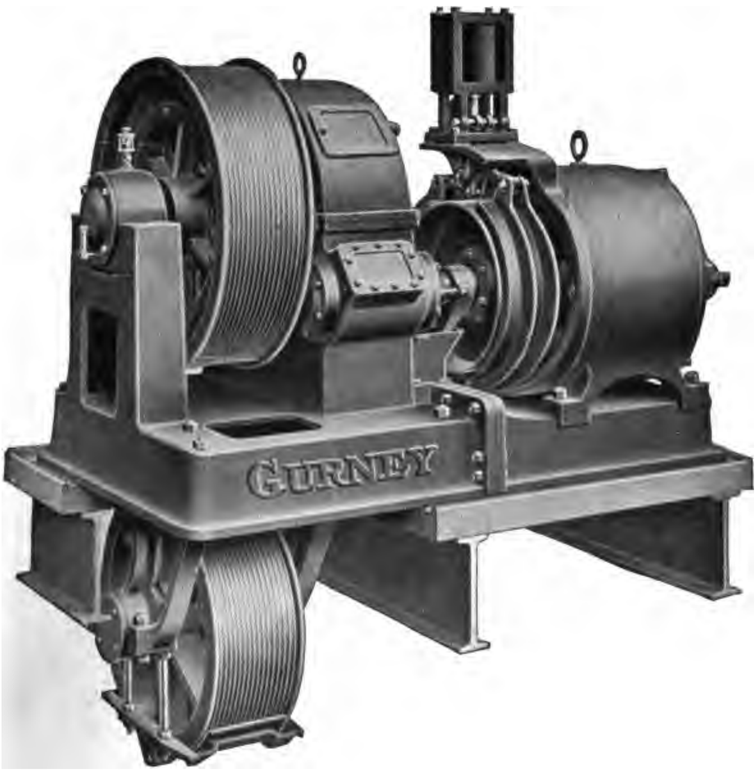


Fig. 165. Gurney Type of Traction Elevator
Courtesy of Gurney Elevator Company

Oil Buffers. In addition to the above safeguards, oil buffers are used below the car and the counterpoise weight, one type being shown in Fig. 166. The device consists of a plunger hanging vertically downward from the car and operating in a hollow cylinder filled with oil. A tank or reservoir of somewhat greater capacity than the cylinder takes care of the excess of oil when the plunger operates. If the car slips by the landing, the lower end of the cylinder strikes a stop such as a pier or beam located at this point for the purpose, and the car or counterweight forces the plunger into the cylinder. The oil escapes into the tank through grooves cut in the surface of the cylinder, but as its passage through these grooves is necessarily slow, the car is slowly brought to rest.

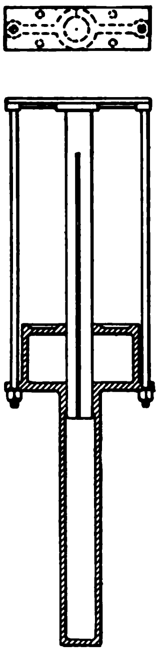


Fig. 166. Oil Buffer Attached to Car

In case the car is at the top landing when a slippage of this kind occurs, the counterpoise weight —which is at the bottom of its travel—performs the office by slackening the cables on the drum as soon as its descent is retarded by the oil buffer, thus destroying the tractive power of the drum for the time being.

Another type of oil buffer which is set in the bottom of the hatchway is shown in Fig. 167.

"One-to-One" Traction Type. The form of drum just described, with its accompanying idler and other accessories, may be used with any high-speed electric engine, whether it be a single worm and gear or a tandem machine. The latter are more frequently used, however, because the wear is divided between two worms and gears and the mechanism is less liable to heat or get out of order. These geared machines, however, are suitable only for moderately high speeds up to 400 f. p. m.; when a higher speed is desired, another form—known among elevator makers as the "one-to-one" engine—has been adopted. It derives its name from the fact that the drum performs one revolution to every revolution of the motor, the

Fig. 167. Otis Oil Buffer with Spring Return

drum being keyed directly on the armature shaft, which is extended for the purpose, and an additional or outside bearing provided for its support.

A machine of this type is shown in Fig. 168. A motor of special design is used, which is provided with windings for acceleration and retardation, and whose armature is wound for very slow speeds, viz, 50 r. p. m., and in many cases 35 r. p. m., for the full or normal

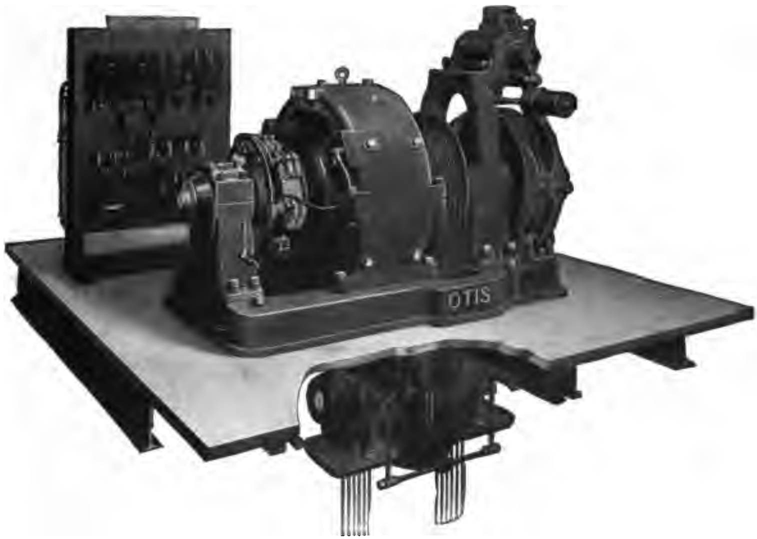


Fig. 168. Gearless Traction Elevator with "One-to-One" Roping
Courtesy of Otis Elevator Company

speed. A motor running at either of these speeds and a drum of, say, 34-inch diameter will produce a car speed of from 300 to 450 f. p. m., and with a little higher motor speed, say 60 to 70 r. p. m., a car speed of from 500 to 600 f. p. m. may be obtained.

When engines of this type are used, the armature shaft must be of ample diameter—5 inches to 6 inches according to the duty required of it—and the drum must be cast with a broad and heavy brake pulley integral with it. This pulley is of the same diameter as the drum, has a full 12-inch face, and has fitted to it a very powerful brake, applied in the usual manner by strong spiral springs and a very powerful solenoid for the release. The method of control of this elevator is similar to that used with the geared machine except that the motor is fitted with a speed governor driven from the armature shaft, which is designed, in case of undue speed, to close a circuit to the solenoid, and at the same time to open the main circuit and thereby stop the engine.

"Herringbone" Spur-Gear Type. The latest type of electric elevator is what is called the "herringbone" spur-gear machine, Fig. 169. It consists of the usual bed plate with gear case, drum, bearings, and motor, mounted upon it, but instead of the worm and gear, a bronze spur gear and pinion are used to drive the drum. The ratio between gears is about 5 to 7 and the teeth in gear and

Fig. 169. **Tandem-Gear Elevator with Herringbone Reduction Gearing**
Courtesy of Gurney Elevator Company

pinion converge from the center of its face outward at an angle of about 60 degrees, Fig. 170; hence the name herringbone.

There is nothing new about this type of spur gear, as it has been in use for mill purposes for at least a century. It was originally designed to impart a smoother motion to the driven machines and also to give greater strength to the teeth, but until recently the only method of producing it was by casting and, of course, cast gears were not applicable to elevator service. However, cut gears of this description have now been successfully produced and they are being adopted in many other lines.

The advantages of the herringbone gear are a minimum of friction as compared with the worm and worm gear; smoother running than with the teeth cut straight across the face; and greater

Fig. 170. Helical Gear Rim, Pinion, and Brake Pulley
Courtesy of Gurney Elevator Company

strength due to the diagonal position of the teeth, which allows a greater number of teeth to be in mesh with the pinion at one time.

The disadvantage, which is common to all spur gears, is its extreme liability to race when lowering a heavy load or when an empty car is ascending. To guard against this, the engine must be provided with a centrifugal governor, Fig. 171, on the pinion shaft, which applies a brake momentarily when a certain speed is exceeded.

In this machine the motor is coupled to the pinion shaft to which the braking device is attached. The hoisting drum is provided with a heavy wide brake pulley such as is used on the

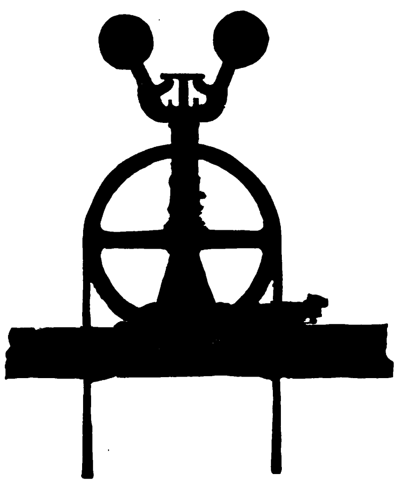


Fig. 171. Gurney Centrifugal Safety Governor Thrown into Operation

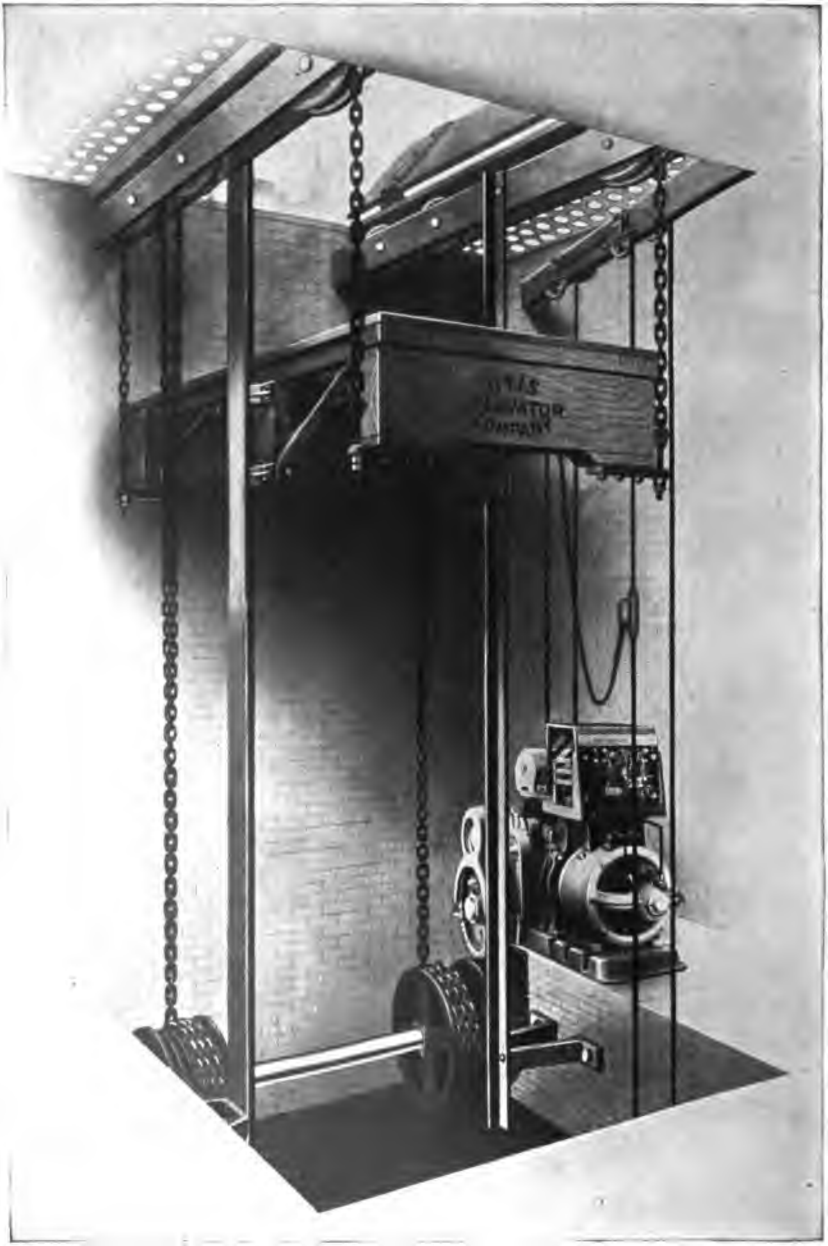


Fig. 172. Otis Elevator Sidewalk Lift
Courtesy of Otis Elevator Company

"one-to-one" type, and a powerful brake is provided which is used only in emergencies. This brake is applied by means of a lever and weight, which are held out of service by a latch or bolt arranged to be tripped by another centrifugal governor when a dangerous speed is attained. The motor used runs at a higher speed than that used with the "one-to-one" engine, but at a lower speed than that used with the worm and gear.

Difficulties with Traction Types. With all traction elevators, no matter whether driven through the medium of gearing or directly from the armature shaft, there is a danger of slippage of the cables on the driving drum, especially if the cables become greasy. This slippage is most noticeable when the operator endeavors to stop in descending with a heavy load. This is especially true if the speed is high and the attempt is made to stop quickly, the car sometimes sliding past the landing even to the extent of a story or two; should this occur (and it has done so in many instances) at the lower landing, a very unpleasant jar results.

The cause of this slippage is usually insufficient counterpoising, or if the building is at least twelve stories, it is probably due in a measure to the preponderance of weight on the car side of the drum, owing to the fact that the cables hang almost wholly in the hatch above the car. The remedy in such a case is the use of the chain counterpoise.

Miscellaneous Elevators. *Single-Belt Type.* There are other forms of electric elevators which are occasionally used. One of these, known as the single-belt elevator, consists of a worm-geared machine, hung from the ceiling of the room and adjacent to the hatchway, and driven by a motor through the medium of a leather belt. No countershaft is used, but the motor, which is reversible, is also located on, or hung from, the same ceiling at a distance of eight or nine feet from the winding gear, and drives it by means of the above mentioned belt. The motor is provided with a sliding base frame and screws in order to compensate for stretch of belt; the controller is attached to the frame or casing of the winding gear and is properly wired to the motor.

Sidewalk Type. Another type is the electric sidewalk or basement lift, Fig. 172. It is heavily built and is driven by a small electric engine.

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